



**HTC 2010** 4<sup>th</sup> EUROPEAN HTC 2010, Versailles, France



## TECOSIM Technische Simulation GmbH

Vision: Global Leader in Computer Aided Engineering (CAE)

Advanced laminated glass modeling for safety FEA using RADIOSS,  
current status of the TECOSIM internal research project

Dr. Martin Konrad (CAE Specialist)  
Dr. Zhongming Xia (CAE Analyst)  
Mark Gevers (General Manager)



TECOSIM



Scope



Status @EHTC'09



Improvements



Conclusion



Outlook

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- TECOSIM
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## TECOSIM

**Business Area:** TECOSIM is Europe's largest, independent service provider in Computer Aided Engineering (CAE) – the computer-based development and optimization of components, structures, and products



## Scope

**Markets:** Original Equipment Manufacturers (OEMs) and suppliers in automotive, chemical, aerospace, medical, and consumer good industries



## Status @EHTC'09



## Improvements

**Foundation:** 1992

**Turnover:**

2010:	20 Mio. Euro (Schedule)
2009:	18 Mio. Euro
2008:	20 Mio. Euro
2007:	18 Mio. Euro
2006:	12 Mio. Euro



## Conclusion

**Employees:**

2010:	302 employees
2009:	240 employees
2008:	240 Employees
2007:	210 Employees
2006:	150 Employees



## Outlook

**Vision:** Global Leader in Computer Aided Engineering



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## Locations



● Locations

● Cooperations/Partners

## TECOSIM

## Scope

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## References (Selection)

- Adam OPEL
- AUDI
- BMW
- Daihatsu
- Daimler
- FIAT
- FORD
- GM Daewoo
- Honda
- Hyundai/Kia
- Isuzu
- Jaguar
- MAN  
(Commercial V.)
- Land Rover
- Nissan
- Porsche
- Renault
- Toyota
- Volkswagen
- Autoliv
- Benteler
- Bombardier
- Bosch
- Boysen
- Brose C.R.
- Hammerstein
- Continental  
Automotive
- DLR
- Dura Automotive
- Dynamit Nobel
- Deutz
- EADS
- Elring
- Klinger
- Evobus
- Fendt
- Georg Fischer
- Getrag FORD Transmissions
- Getrag
- Faurecia
- Hella
- HBPO
- IAC Johnson Controls
- Karmann
- Keiper
- Kirchhoff
- Lear
- Magna Group
- MBTech
- Montaplast
- Plastal
- Perkins
- Recaro
- Röchling
- Siemens Power Generation
- Takata-Petri
- TRW
- ThyssenKrupp
- Visteon
- Waldaschaff Automotive
- ZF- Sachs
- etc.

**TECOSIM**

**Scope**

**Status @EHTC'09**

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## ▪ Vehicle CAE

HS/LS-Crash  
Pedestrian Protection  
Dynamics/NVH/Acoustics  
Stability/Durability  
CFD/Aerodynamics

## ▪ Seats CAE

ECE-xx  
Dynamics  
Stability

## ▪ Interior CAE

Occupant Protection  
Restraint Systems  
CFD/HVAC  
Interior Concepts

## ▪ CAE Consulting

CAE-Processes  
Product Optimisation  
Software/Hardware  
Training

## ▪ CAE Products

TEC|BENCH™  
TEC|ODM™  
TEC|PROM™  
TEC|WORX

## ▪ Subsystems CAE

Stability/Durability  
Dynamics/NVH  
Structural Optimisation  
D.O.E.  
Crash  
CFD

## ▪ Advanced CAE

New Vehicle Concepts  
CAE-Material Validation  
Barrier Development  
CAE Process Chain

## ▪ Powertrain CAE

Dynamics/NVH  
Stability/Durability  
CFD/UTM  
Acoustics

## ▪ Chassis CAE

Dynamics/NVH  
Stability/Durability  
Impact Simulation  
Drive over Curb  
MKS/MKS-Structure Coupling

TECOSIM

Scope

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Improve predictability

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## Motivation

Regarding pedestrian protection the head impact on the windscreen of a car is focused by several legal requirements and many consumer tests (NCAP) all over the world.



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## Improve predictability

Based on an R&D project for FORD presented at the EHTC'09 TECOSIM establishes a project funded by the Federal Ministry of Economics and Technology for further improvements of the laminated glass model.

Scope

Motivation

- Improve predictability

Targets

Status @EHTC'09

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Scope

Motivation

Improve predictability

Targets

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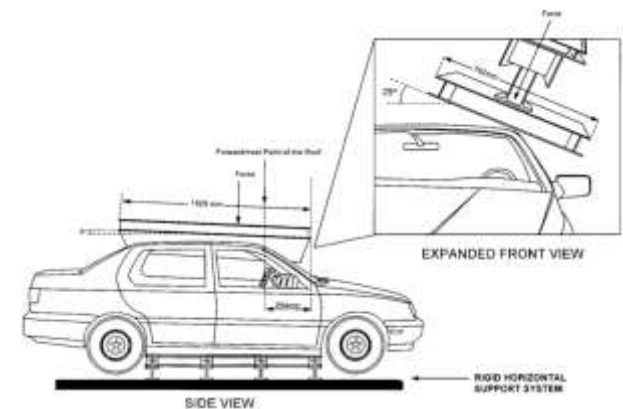
Improvements

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Outlook

## Targets

- improve laminated glass model for windshield modeling
- get better test correlation with respect to glass failure
- one windshield model for all load cases (one set of parameters!)
- respect turn-around-time requirements for full vehicle CAE analysis
- no negative effect on time step allowed
- support all mayor codes (RADIOSS, LS-DYNA, PAM-CRASH, ABAQUS)



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## Status at EHTC'09: FORD R&D project

- Focus: pedestrian head impact

Scope

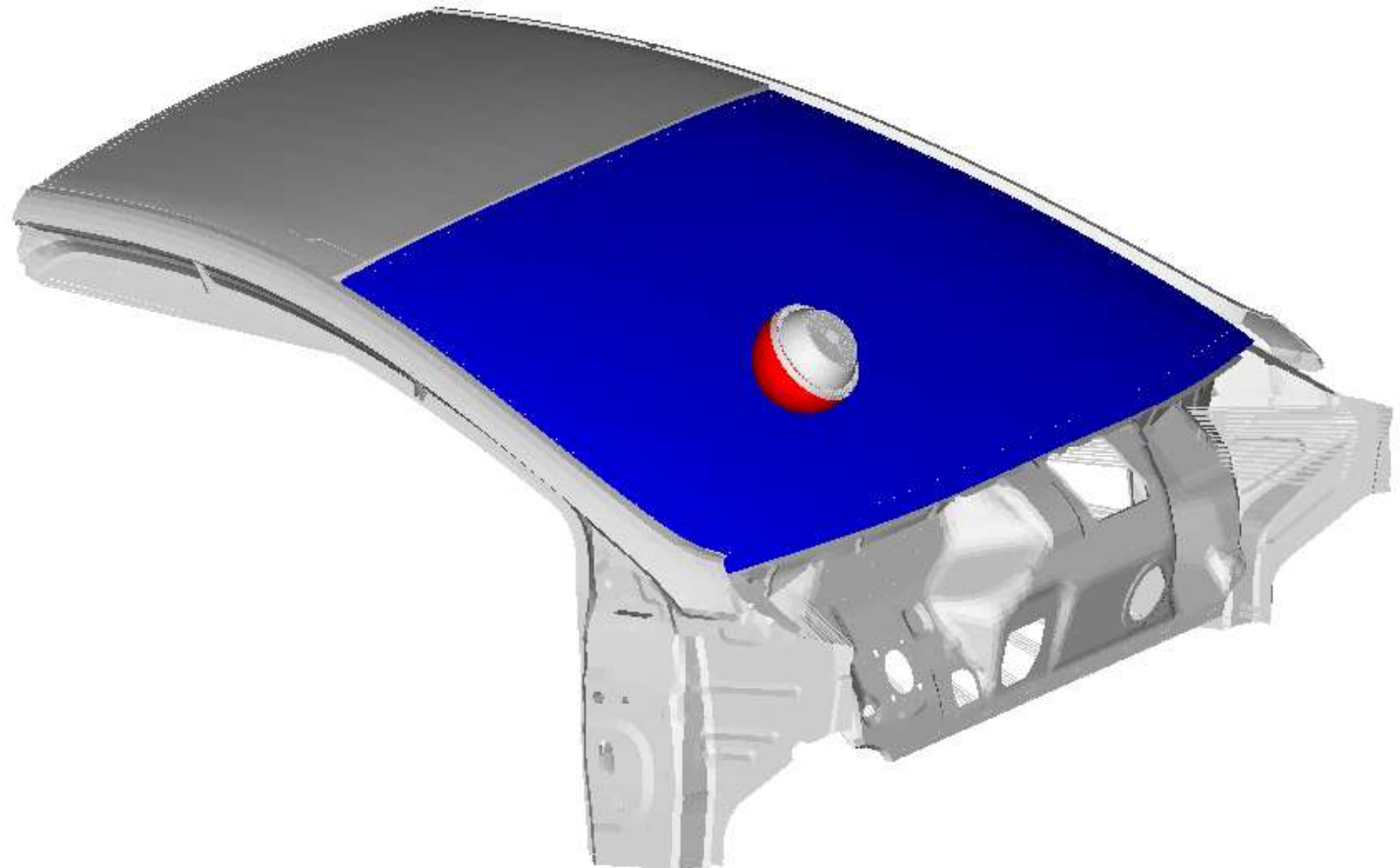
### Status @EHTC'09

- FORD R&D project
- Open issues

Improvements

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FORD Mondeo, Model 2007

TECOSIM

Scope

Status @EHTC'09

- FORD R&D project
- Open issues

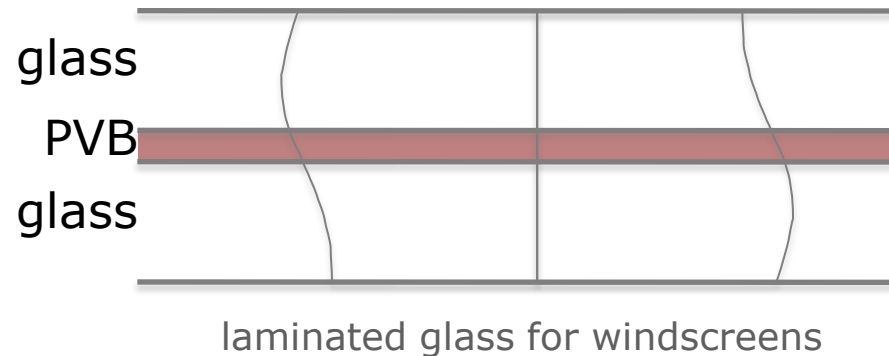
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## Status at EHTC'09: FORD R&D project

- Focus: pedestrian head impact
- Target:
  - improve predictability of laminated glass model
  - no negative influence on simulation time
  - easy handling



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Scope

Status @EHTC'09

- FORD R&D project
- Open issues

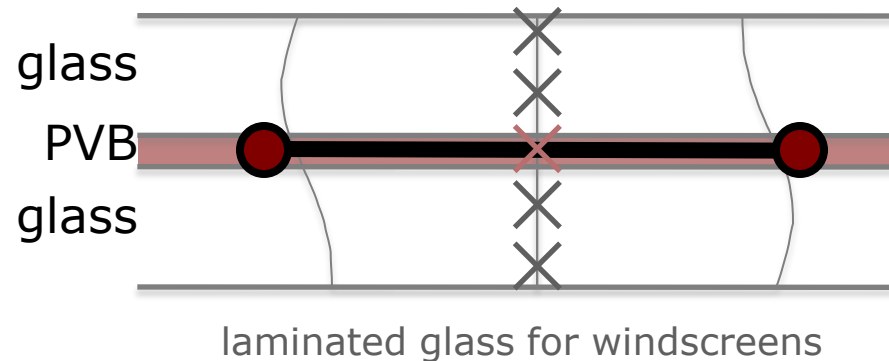
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## Status at EHTC'09: FORD R&D project

- Focus: pedestrian head impact
- Target:
  - improve predictability of laminated glass model
  - no negative influence on simulation time
  - easy handling
- use of RADIOSS multi layered shell





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# Status at EHTC'09: FORD R&D project



Scope

Old elasto-plastic model with regular quad mesh.



Status @EHTC'09

- FORD R&D project
- Open issues



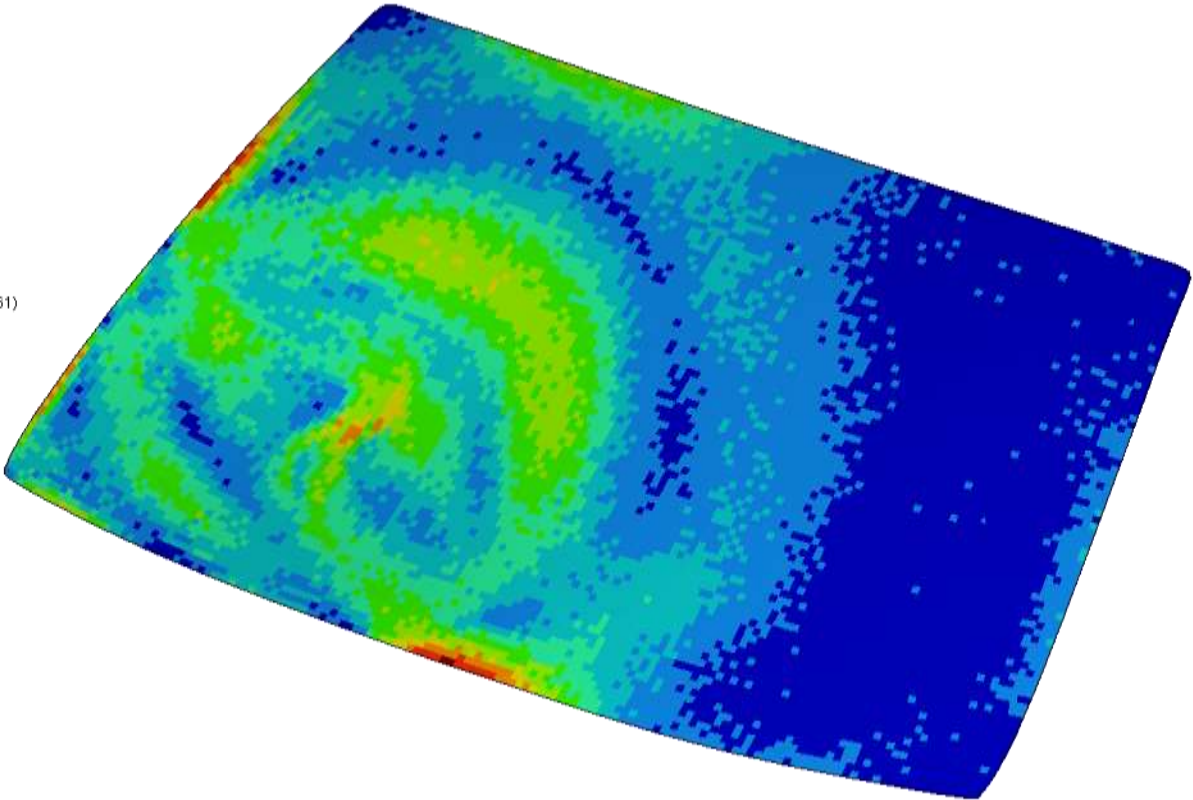
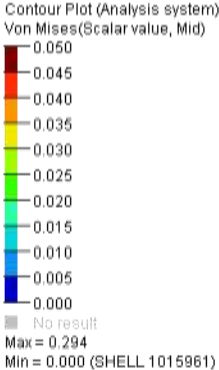
Improvements



Conclusion

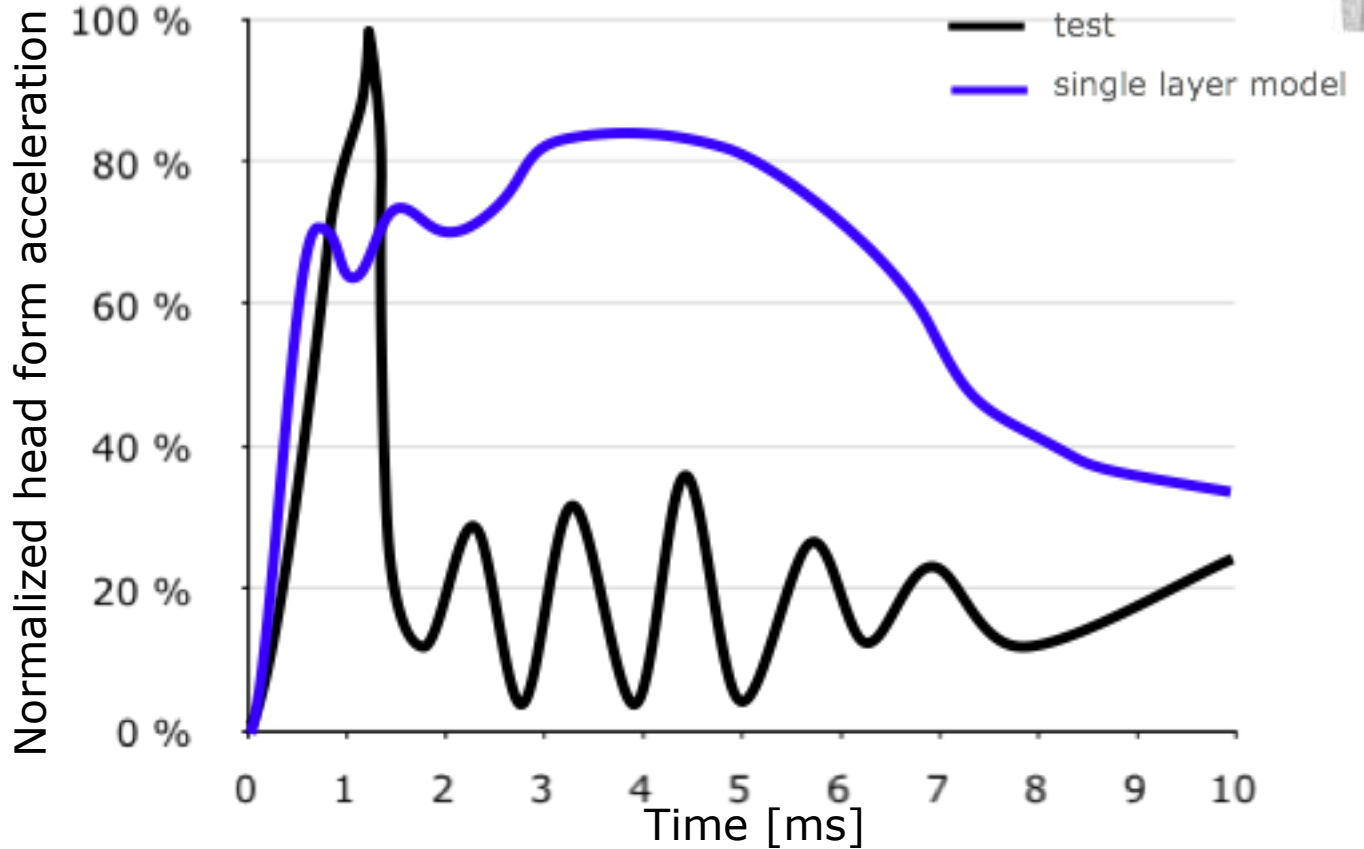
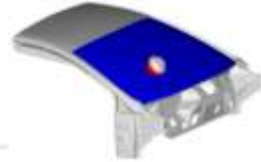


Outlook



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## Status at EHTC'09: FORD R&D project



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## Status at EHTC'09: FORD R&D project

Scope

Respecting glass failure and after various investigation on

- mesh size
- mesh type
- glass properties
- PVB-layer properties
- number of integration points over thickness

Status @EHTC'09

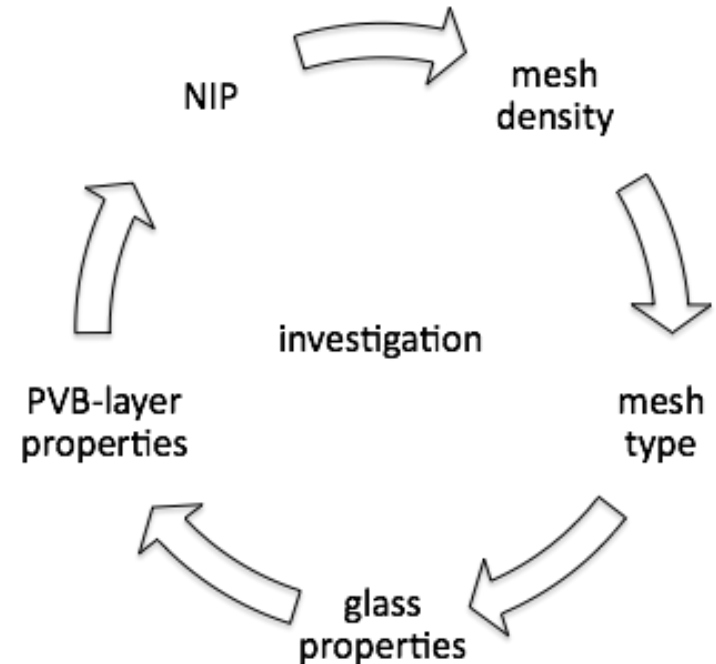
- FORD R&D project
- Open issues

Improvements

we found a highly improved model behavior compared to current state-of-the-art modeling technique

Conclusion

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## Status at EHTC'09: FORD R&D project

Best visual results with circular tria mesh around impact point.

Scope

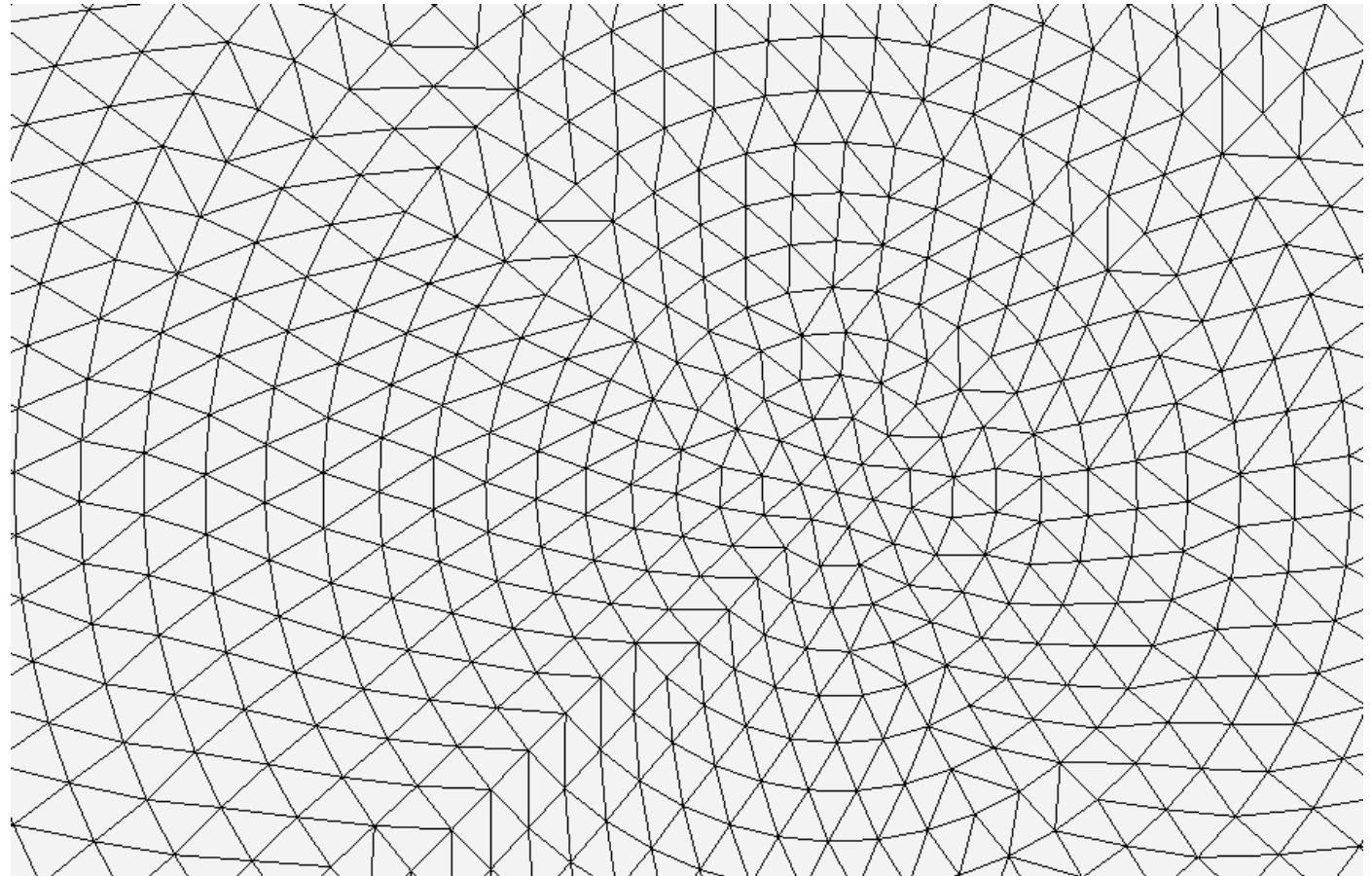
Status @EHTC'09

- FORD R&D project
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Improvements

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The mesh was generated using HyperMesh, controlled by TEC|WORX automation technology.

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## Status at EHTC'09: FORD R&D project

Improved laminated glass model respecting rupture with impact depending mesh.

Scope

Status @EHTC'09

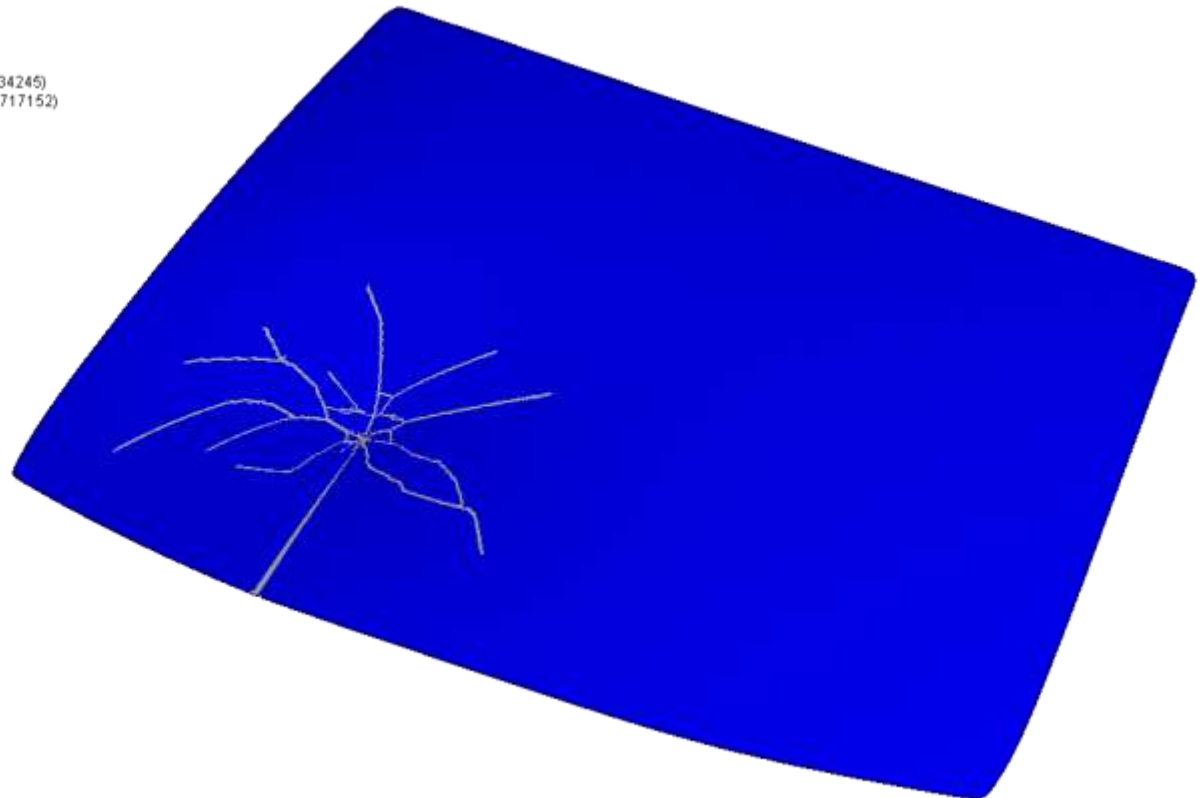
- FORD R&D project
- Open issues

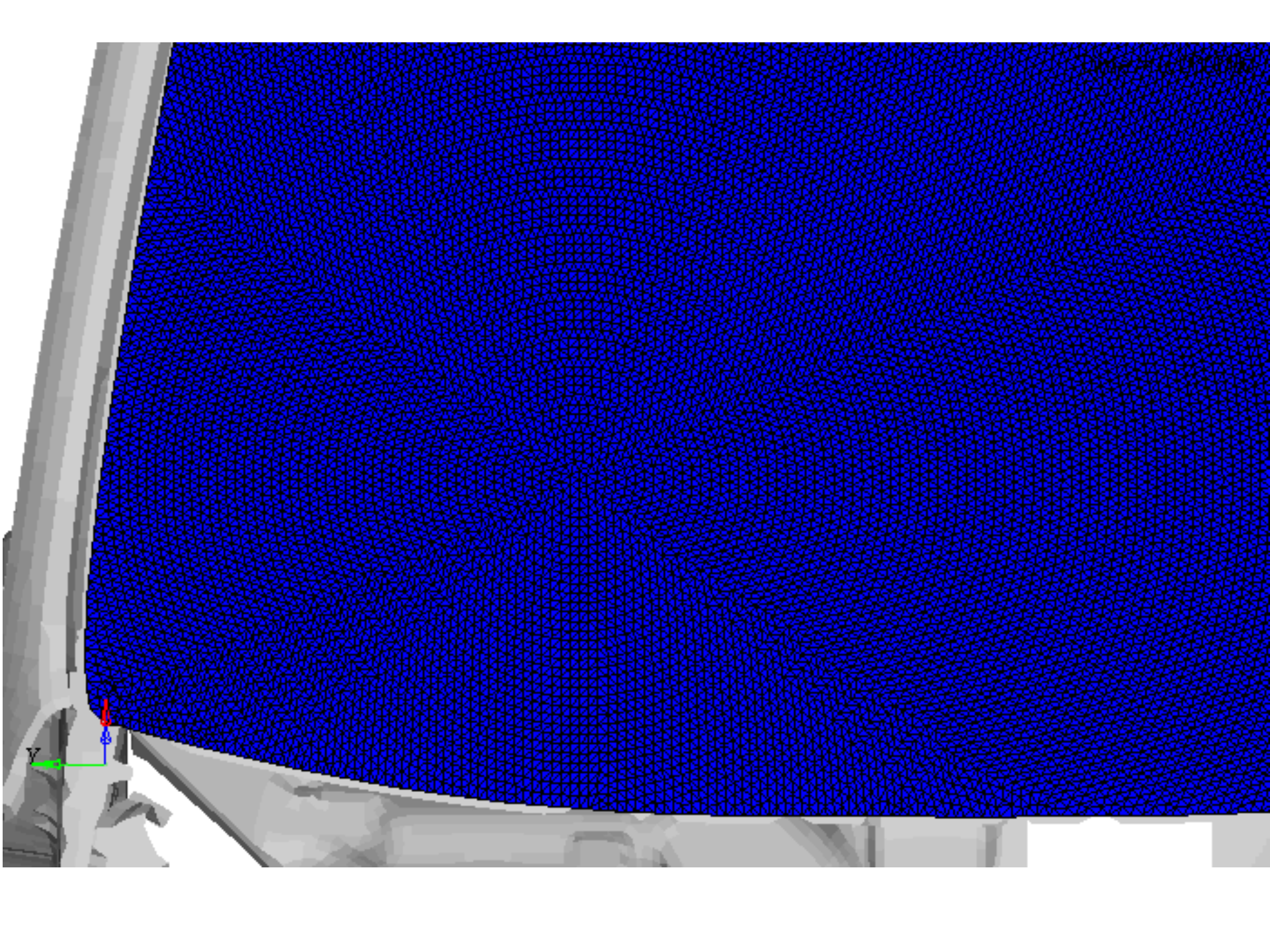
Improvements

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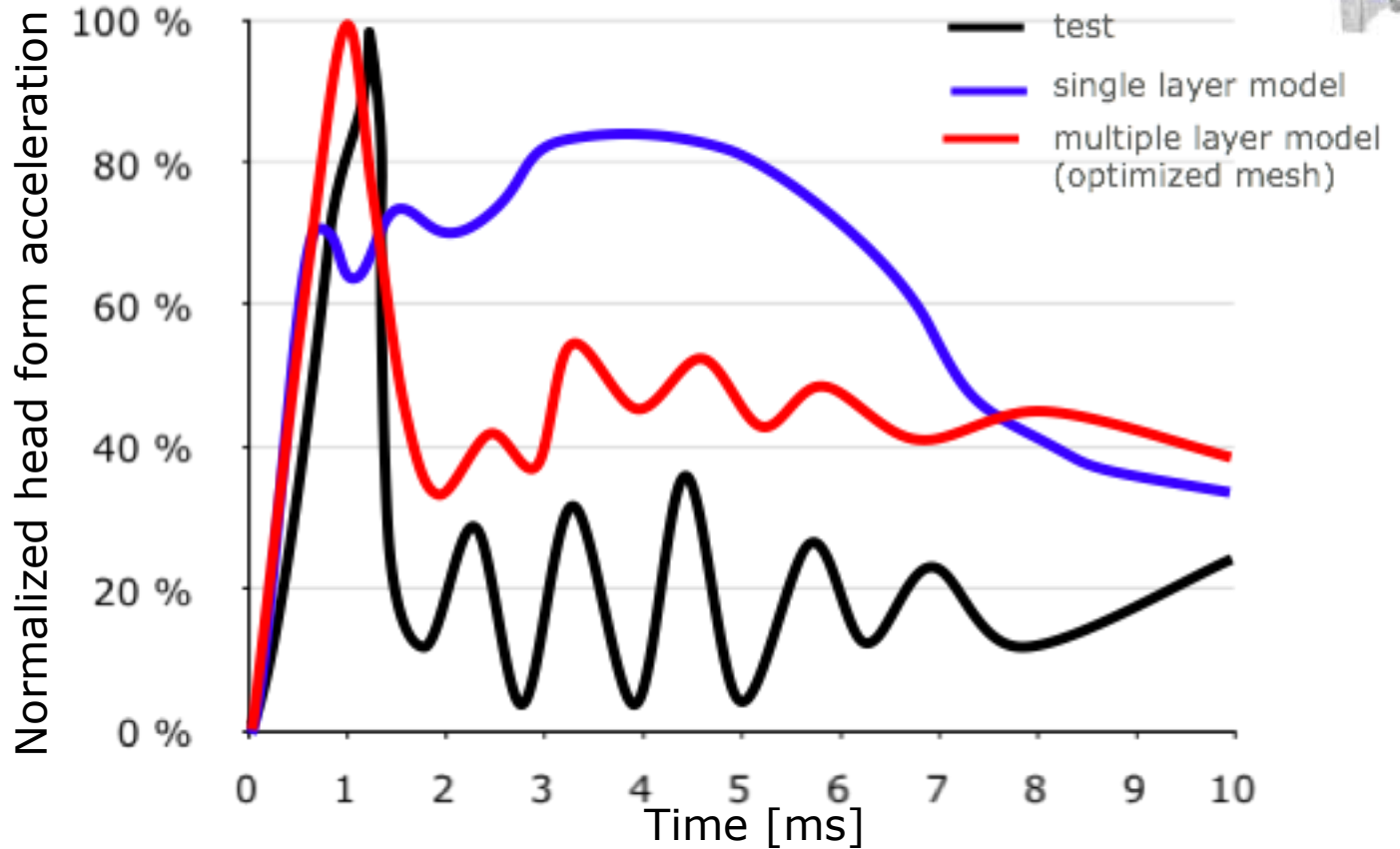
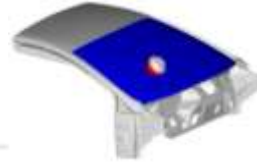
Contour Plot (Analysis system)  
Stress(vonMises, Layer 1)  
2.912E-01  
1.800E-04  
0.000E+00  
No result  
Max = 2.912E-01 (SHELL 34245)  
Min = 0.000E+00 (SH3N 1717152)





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## Status at EHTC'09: FORD R&D project



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## Status at EHTC'09: FORD R&D project

Improved laminated glass model respecting rupture with regular tria mesh.

Scope

Status @EHTC'09

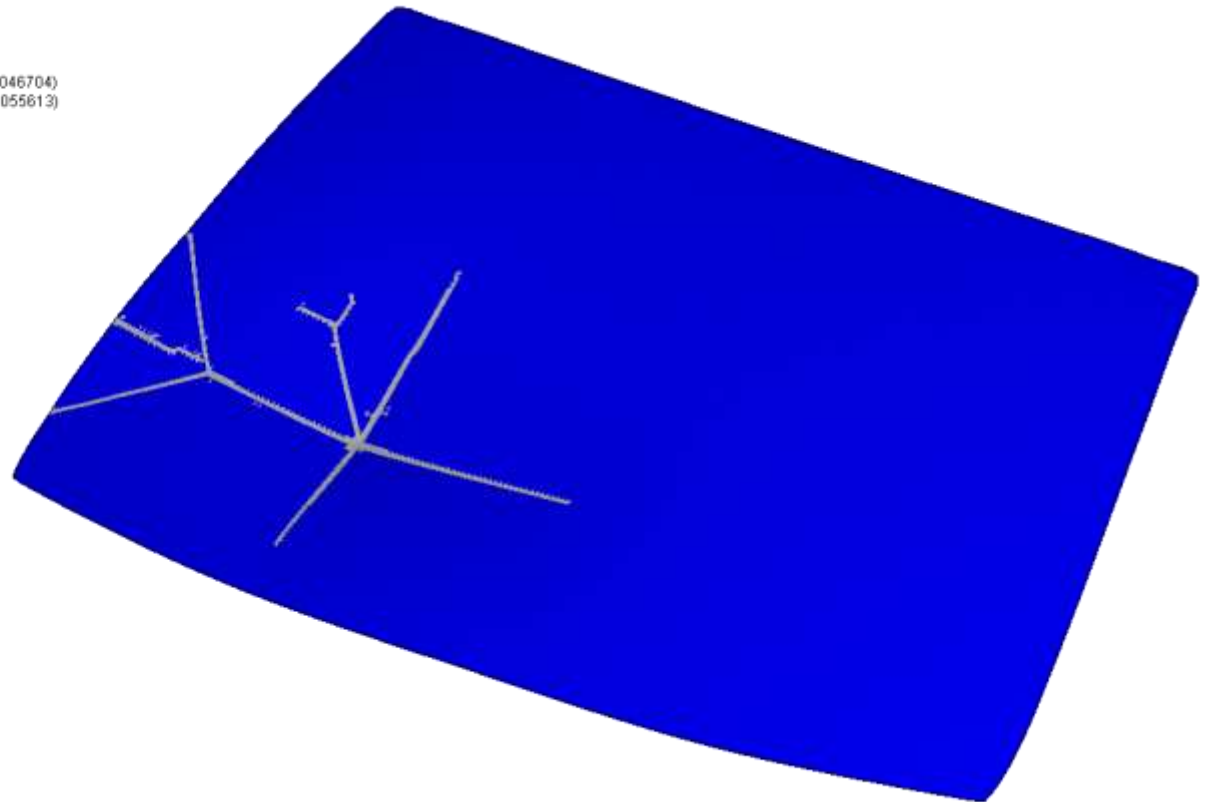
- FORD R&D project
- Open issues

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Outlook

Contour Plot (Elemental system)  
Stress(vonMises, Layer 1)  
2.800E-01  
1.800E-04  
0.000E+00  
No result  
Max = 1.974E-01 (SH3N 5046704)  
Min = 0.000E+00 (SH3N 5055613)





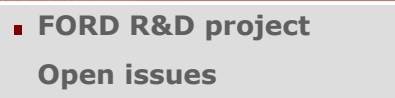
TECOSIM



Scope



Status @EHTC'09



FORD R&D project  
Open issues



Improvements

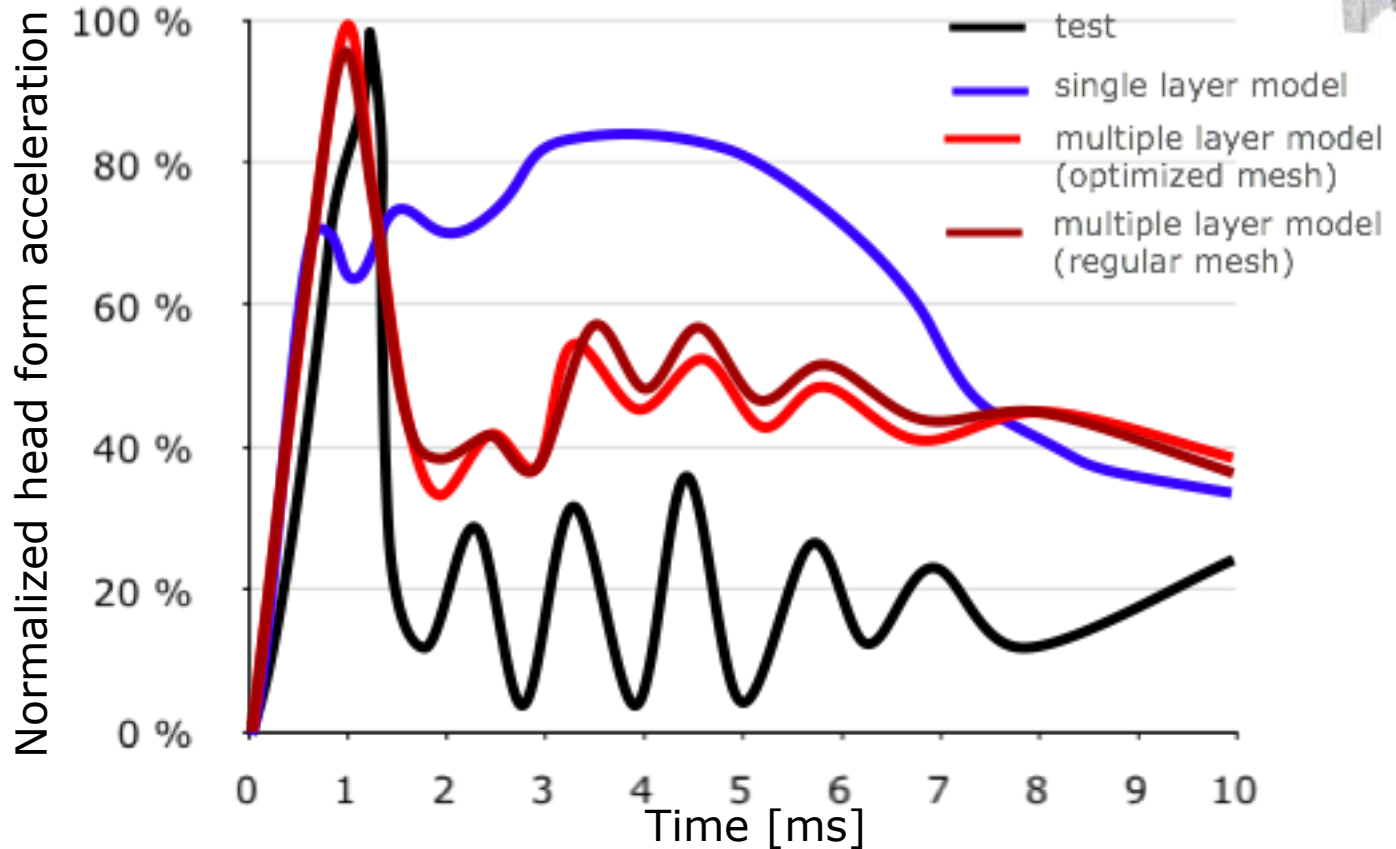
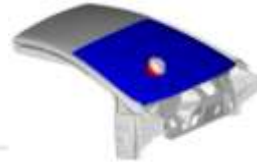


Conclusion



Outlook

## Status at EHTC'09: FORD R&D project

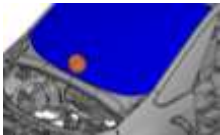


- High influence of glass rupture stress on first peak
- Minor influence of mesh technique: regular tria mesh usable
- Minor influence of glass rupture stress on "after first peak area"
- Minor influence of PVB stiffness



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## Status at EHTC'09: FORD R&D project



Rupture behavior:



Scope



Status @EHTC'09

- FORD R&D project
- Open issues



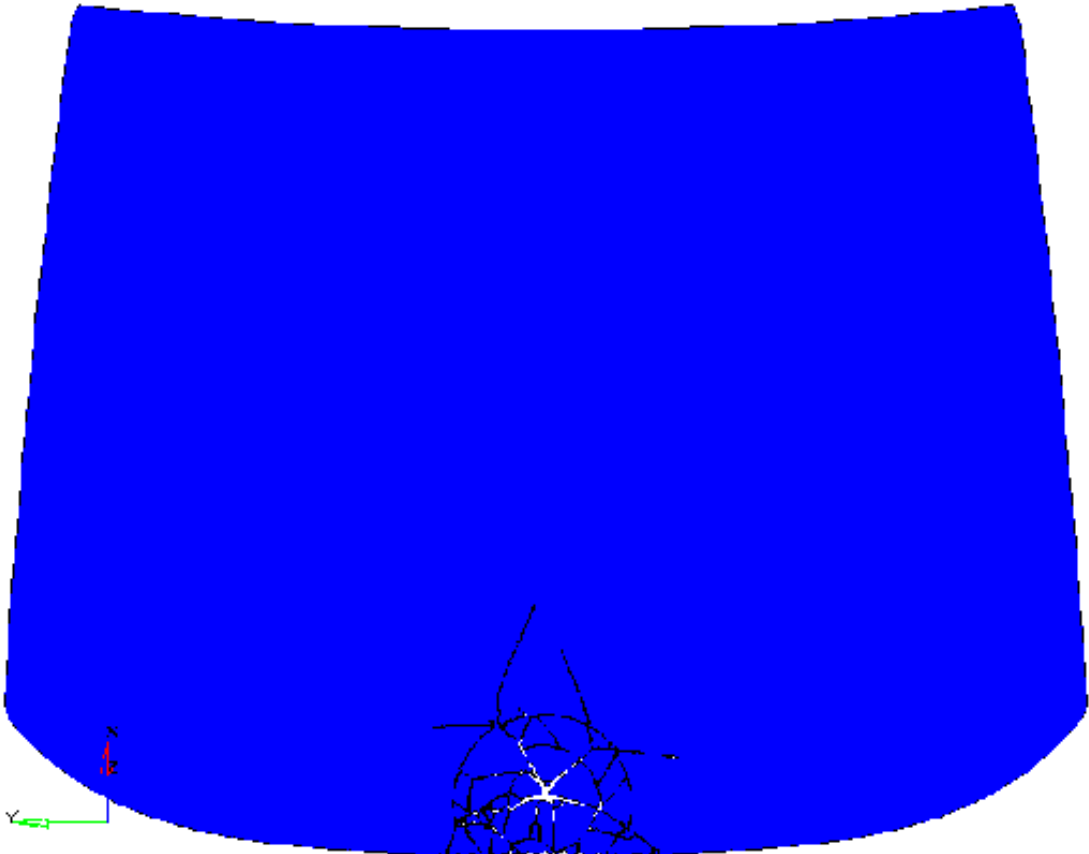
Improvements



Conclusion

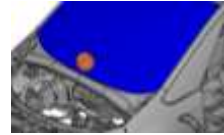


Outlook



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## Status at EHTC'09: FORD R&D project



Rupture behavior:

Scope

### Status @EHTC'09

- FORD R&D project
- Open issues

Improvements

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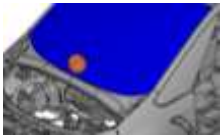
Outlook





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# Status at EHTC'09: FORD R&D project



Scope

Rupture behavior:



Status @EHTC'09

- FORD R&D project
- Open issues



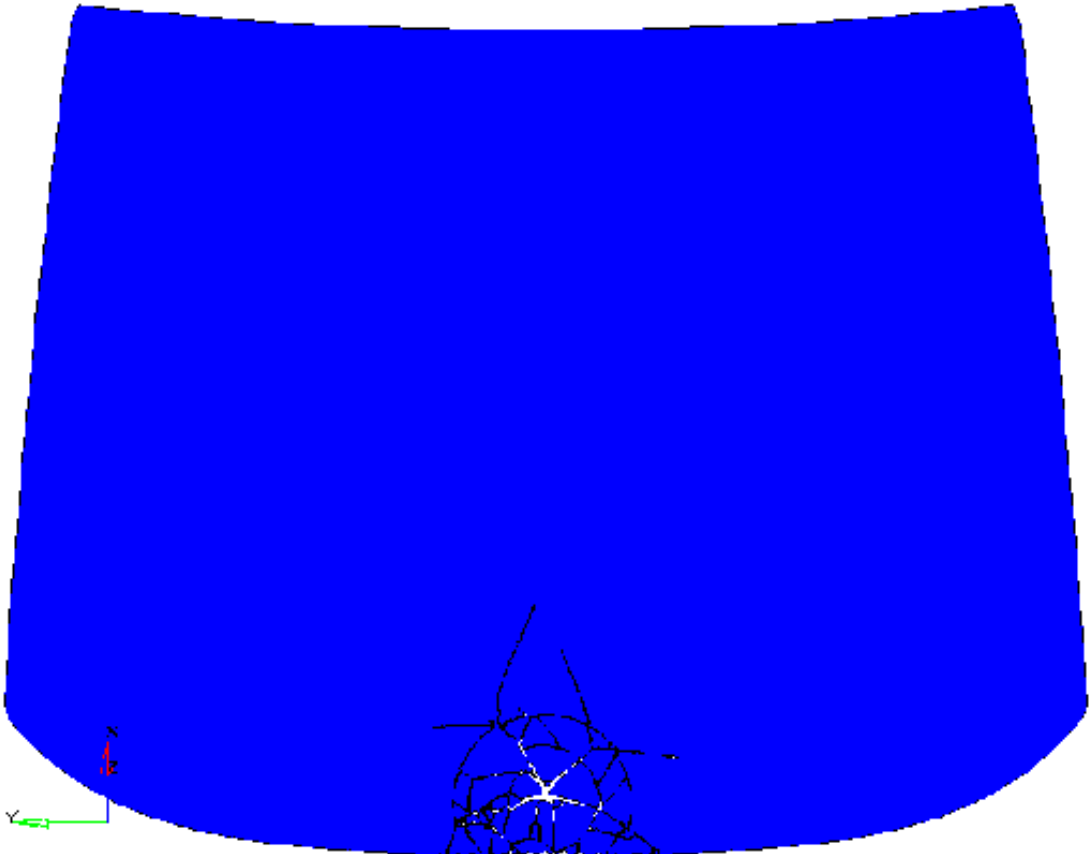
Improvements



Conclusion

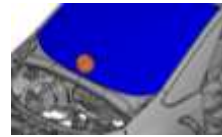


Outlook



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## Status at EHTC'09: FORD R&D project



Rupture behavior:

Scope

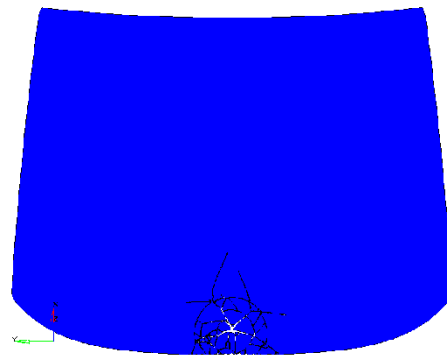
### Status @EHTC'09

- FORD R&D project
- Open issues

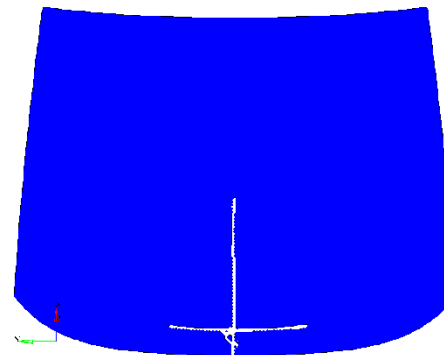
Improvements

Conclusion

Outlook



Fine tria circular mesh



Coarse tria mesh



Test

- Rupture area in test is bigger than in simulation
- Influence of non-physical rupture direction to head form acceleration is less
- Regular impact independent mesh respecting full vehicle time step is usable

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Scope

Status @EHTC'09

FORD R&D project

■ Open issues

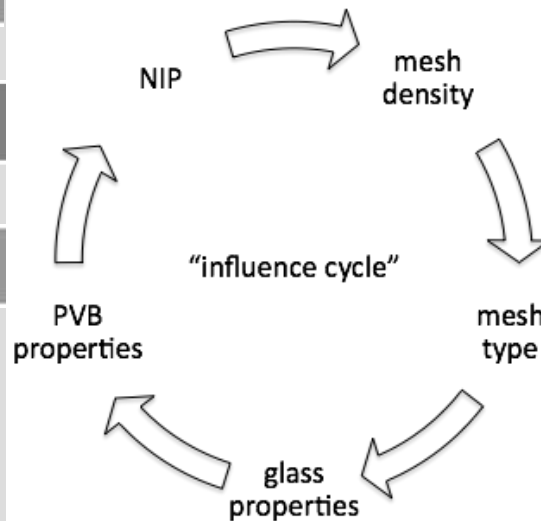
Improvements

Conclusion

Outlook

## Status at EHTC'09: open issues

- Behavior after first breakage:
  - stiffness level is too high
  - crack propagation is less compared to test results
  - no circular cracks in simulation using regular mesh





## Improvements

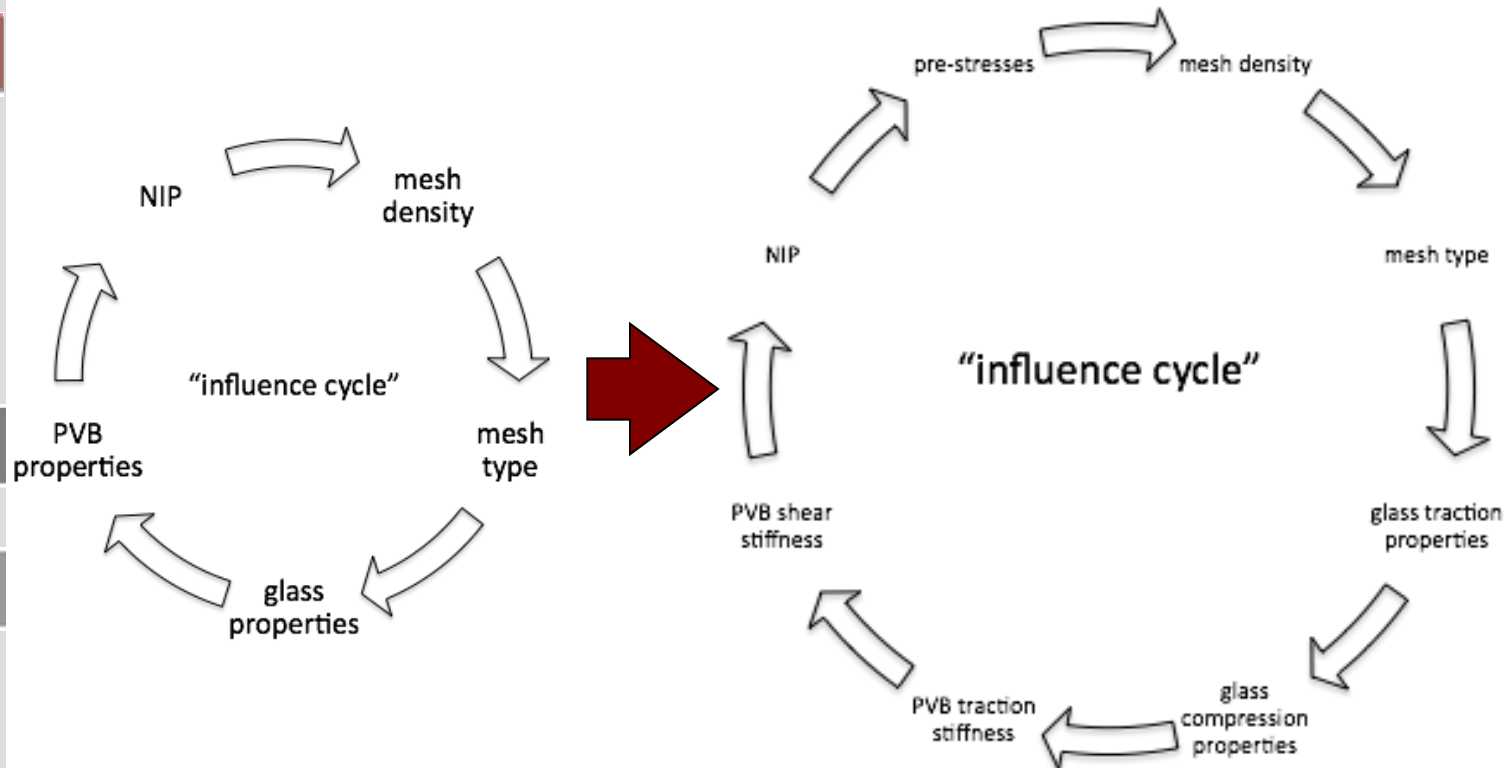
- Influence cycle
- Pre-stresses
- PVB shear stiffness
- Glass properties
- Parameter study
- Current status

## Conclusion

## Outlook

### Improvements: Influence cycle

- Behavior after first breakage:
  - stiffness level is too high
  - crack propagation is less compared to test results
  - no circular cracks in simulation using regular mesh
- Additional influences have to be analysed:



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Scope

Status @EHTC'09

**Improvements**

Influence cycle

- Pre-stresses

PVB shear stiffness

Glass properties

Parameter study

Current status

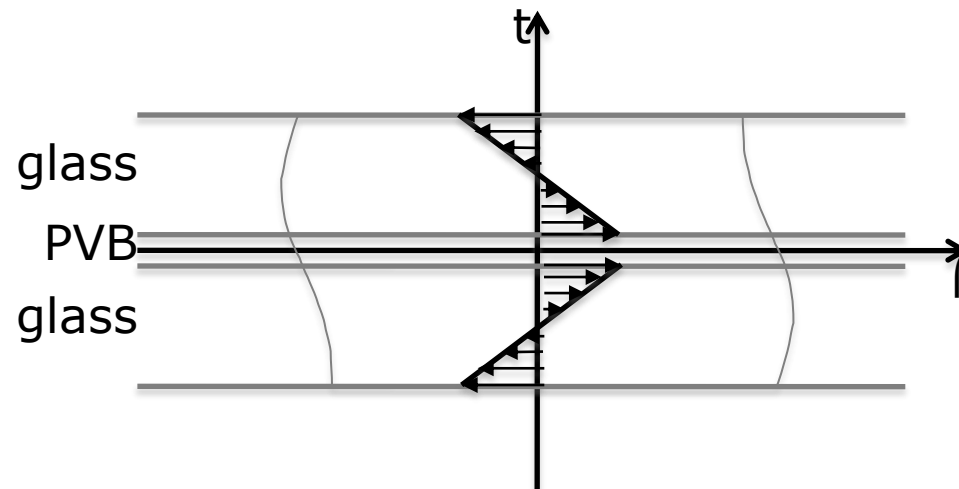
Conclusion

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## Improvements: pre-stresses

- To improve the laminated glass behavior after first breakage a deeper understanding of pre-stress resulting from production process and assembly is needed

Pre-stress situation "2009":



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Scope

Status @EHTC'09

**Improvements**

Influence cycle

- Pre-stresses

PVB shear stiffness

Glass properties

Parameter study

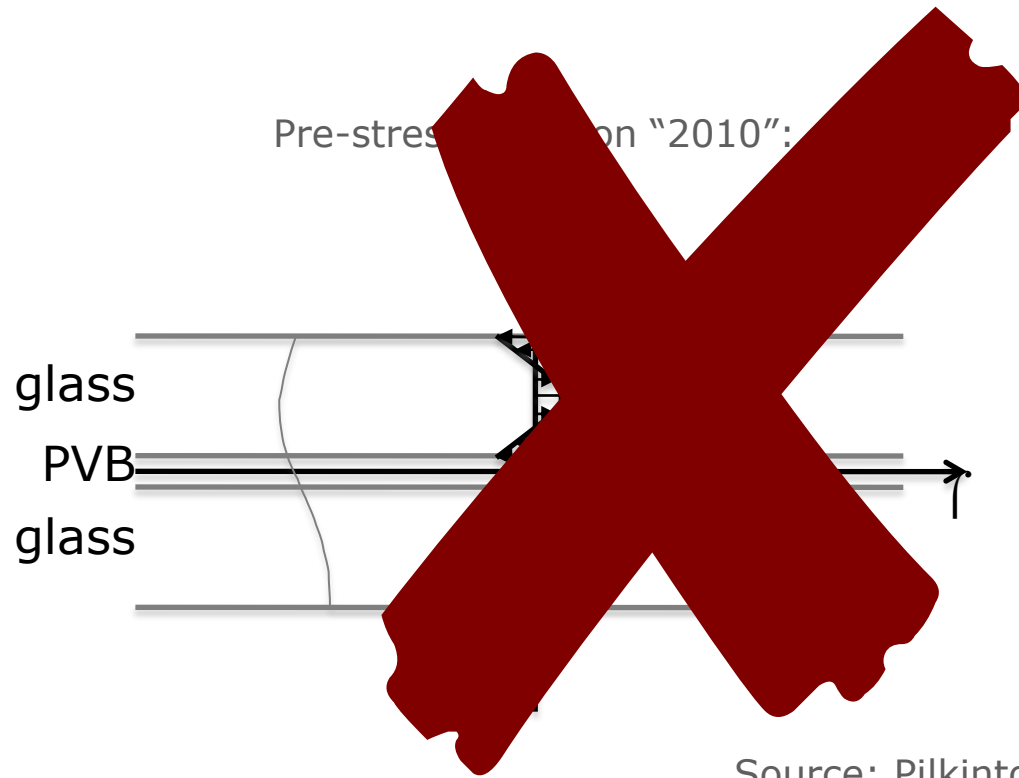
Current status

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## Improvements: pre-stresses

- To improve the laminated glass behavior after first breakage a deeper understanding of pre-stress resulting from production process and assembly is needed



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## Improvements

Influence cycle

Pre-stresses

■ PVB shear stiffness

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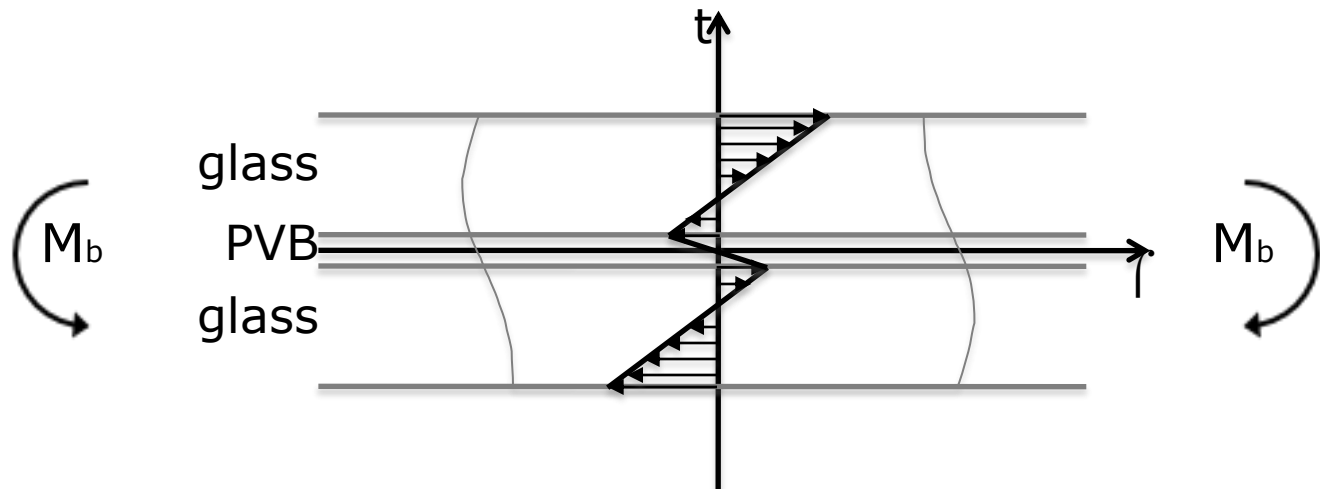
Conclusion

Outlook

## Improvements: respecting PVB layer shear stiffness

- The PVB layer decouples the two glass sheets
- Static bending load results in a non-linear stress pattern

Stress situation under bending load:



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Scope

Status @EHTC'09

Improvements

Influence cycle

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■ PVB shear stiffness

Glass properties

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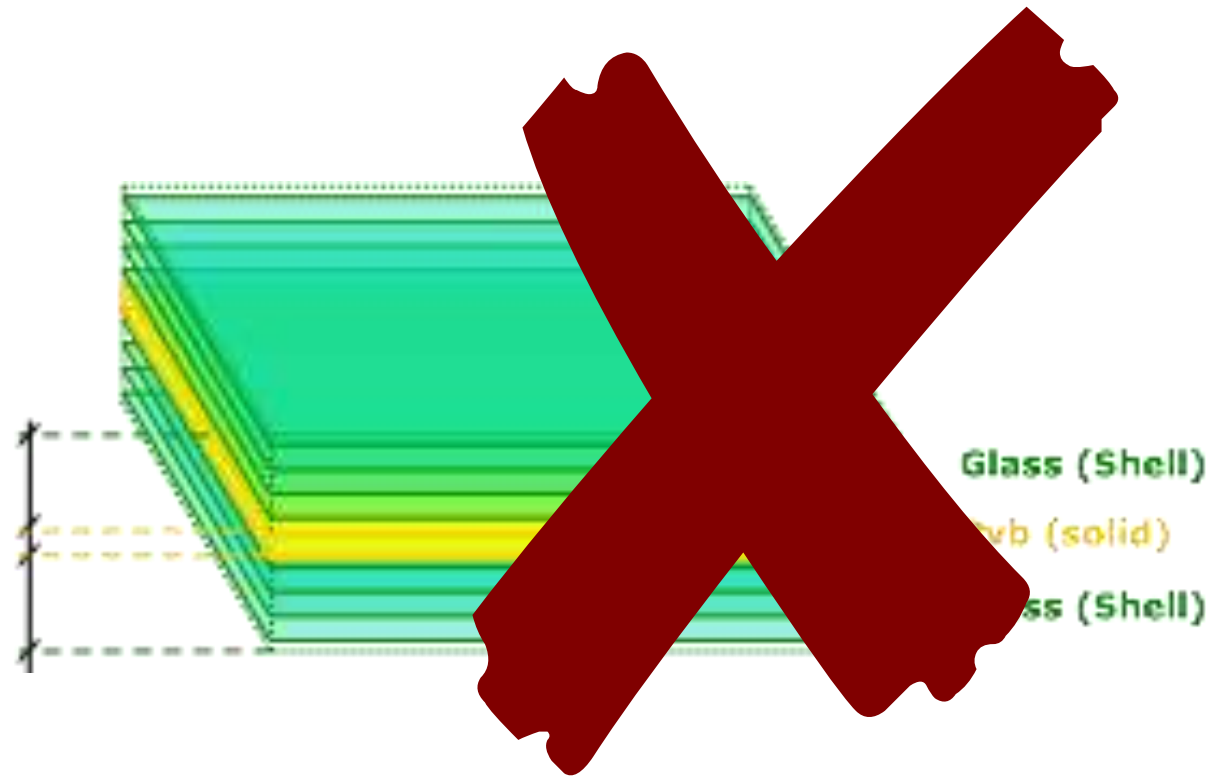
Current status

Conclusion

Outlook

## Improvements: respecting PVB layer shear stiffness

- Respecting PVB shear stiffness only possible with solid elements
- Use shells for glass coupled with solids for the PVB layer



- PVB rate dependence results in highly increased shear stiffness under impact load case

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■ PVB shear stiffness

Glass properties

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## Improvements: respecting PVB layer shear stiffness

Good news:

- stiffness of PVB is massively rate dependent under head impact load case the shear deformation of the very thin PVB layer is less
- choice of multi-layered shell seems to be sufficient

# /PROP/SH\_SANDW



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**Improvements**

Influence cycle

Pre-stresses

PVB shear stiffness

■ Glass properties

Parameter study

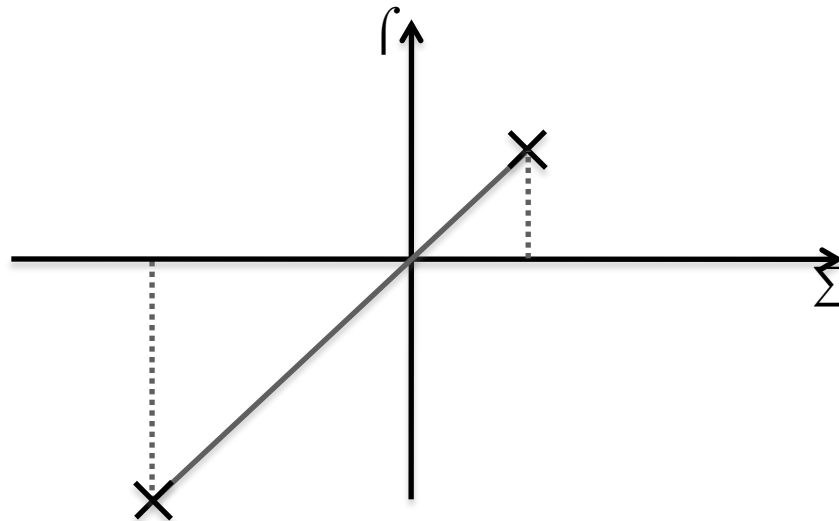
Current status

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## Improvements: respecting different glass properties

- The glass rupture stress is totally different in tensile and compressive direction
- In compressive direction it is up to four times higher
- Therefore the laminated glass under head impact load will only fail in tensile direction



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Status @EHTC'09

**Improvements**

Influence cycle

Pre-stresses

PVB shear stiffness

■ Glass properties

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**Improvements: respecting different glass properties**

- To respect the high compressive stiffness of glass we use the "form limit diagram" failure criteria in RADIOSS:

**/FAIL/FLD**

- Combined with the Brittle material law

**/MAT/PLAS\_BRIT**



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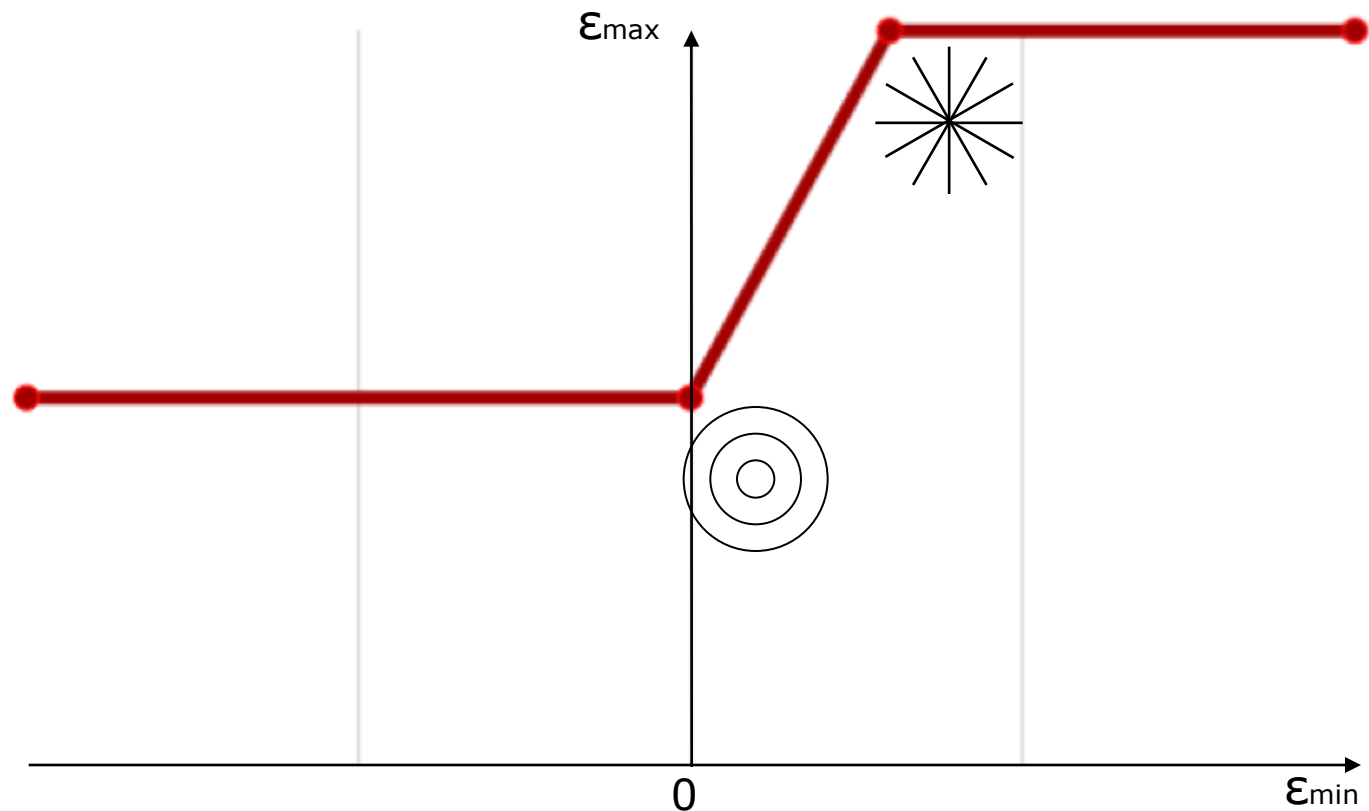
Current status

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## Improvements: respecting different glass properties

- The FLD failure law brings additional benefit: decoupling of failure because of plain stresses and uni-axial stresses
- Crack initiation at impact point because of plain stresses
- Circular cracks initiated because of pure bending



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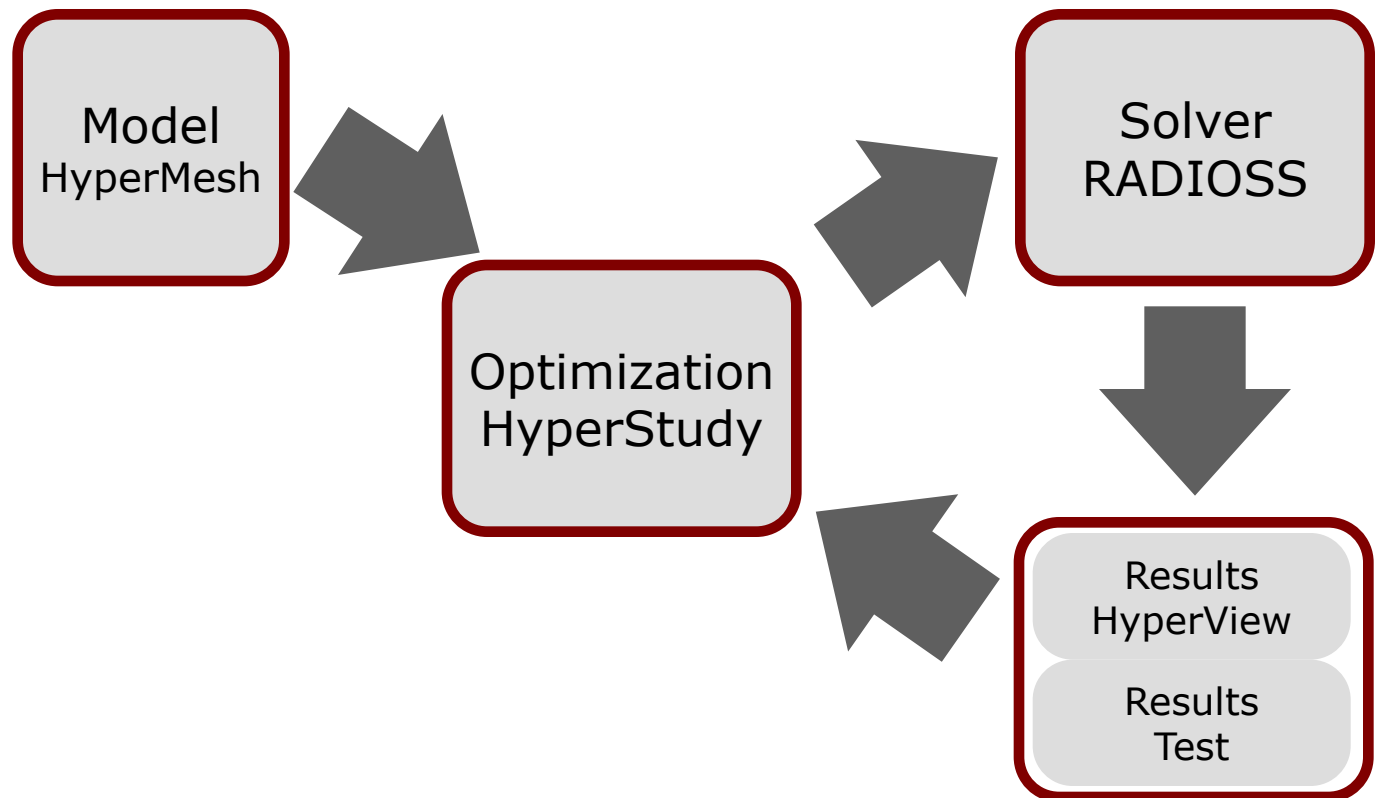
Current status

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## Improvements: automatic parameter study

- The FLD parameters are optimized by HyperStudy



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Scope

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**Improvements**

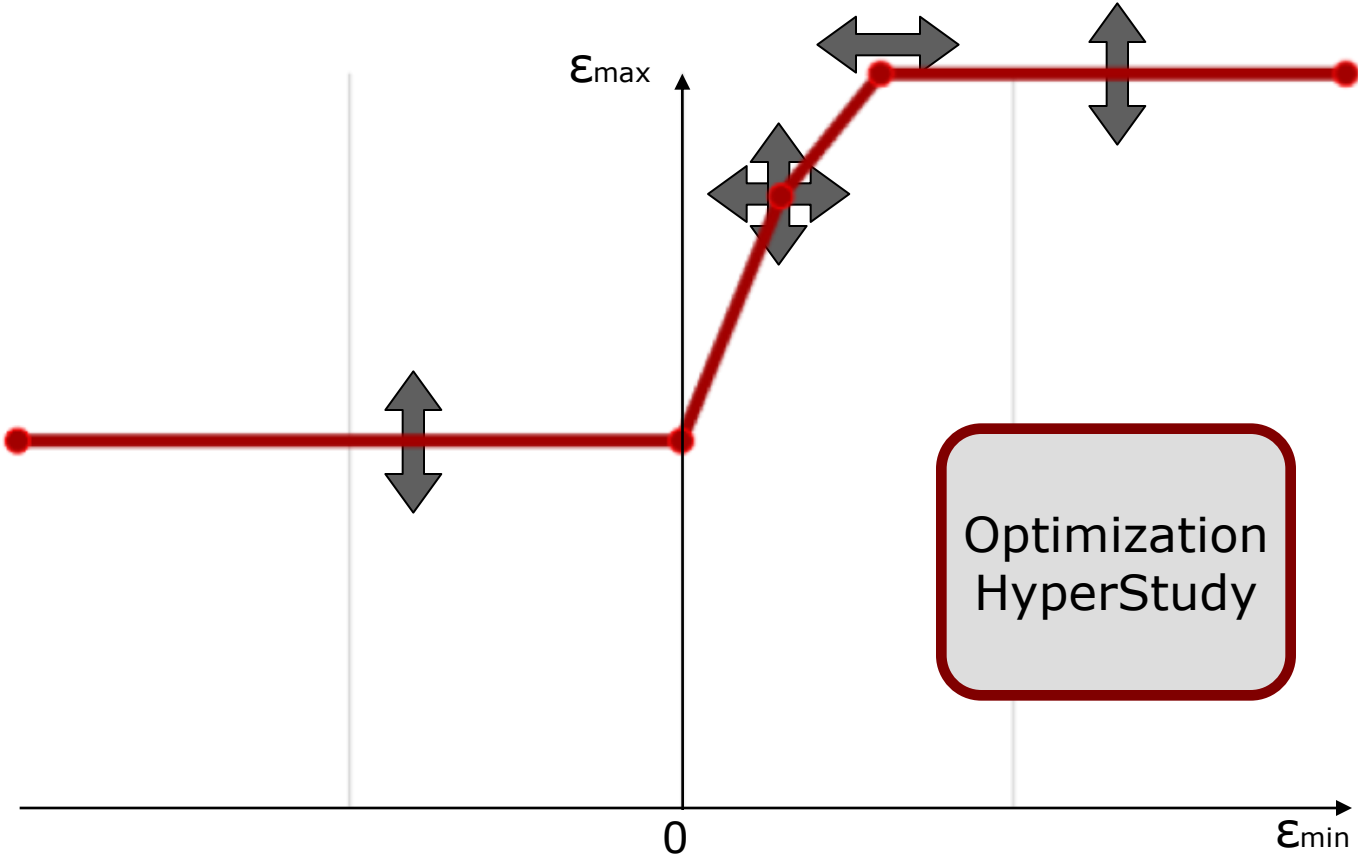
- Influence cycle
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**Improvements: automatic parameter study**

- The FLD parameters are optimized by HyperStudy





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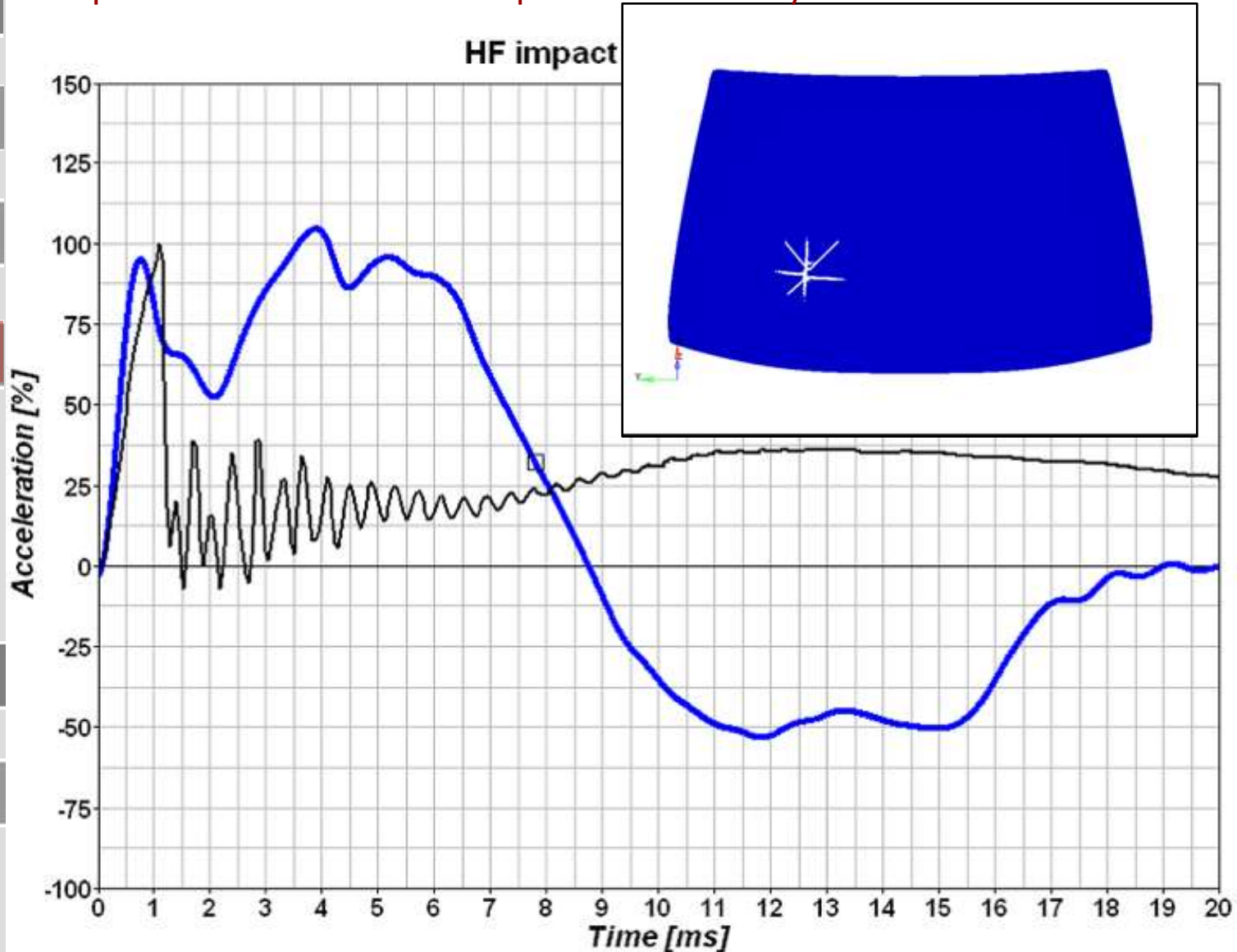


Conclusion



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## Improvements: automatic parameter study



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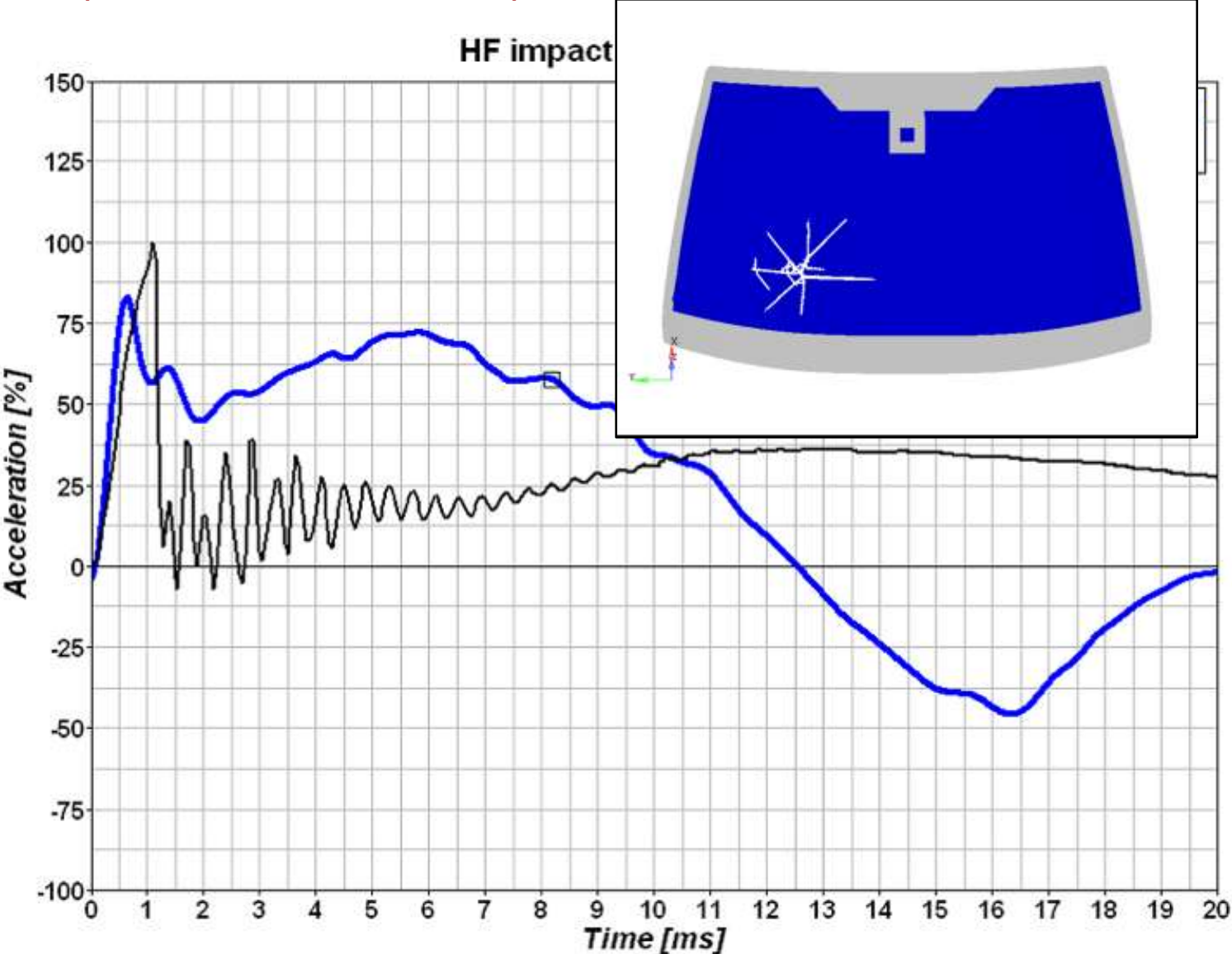
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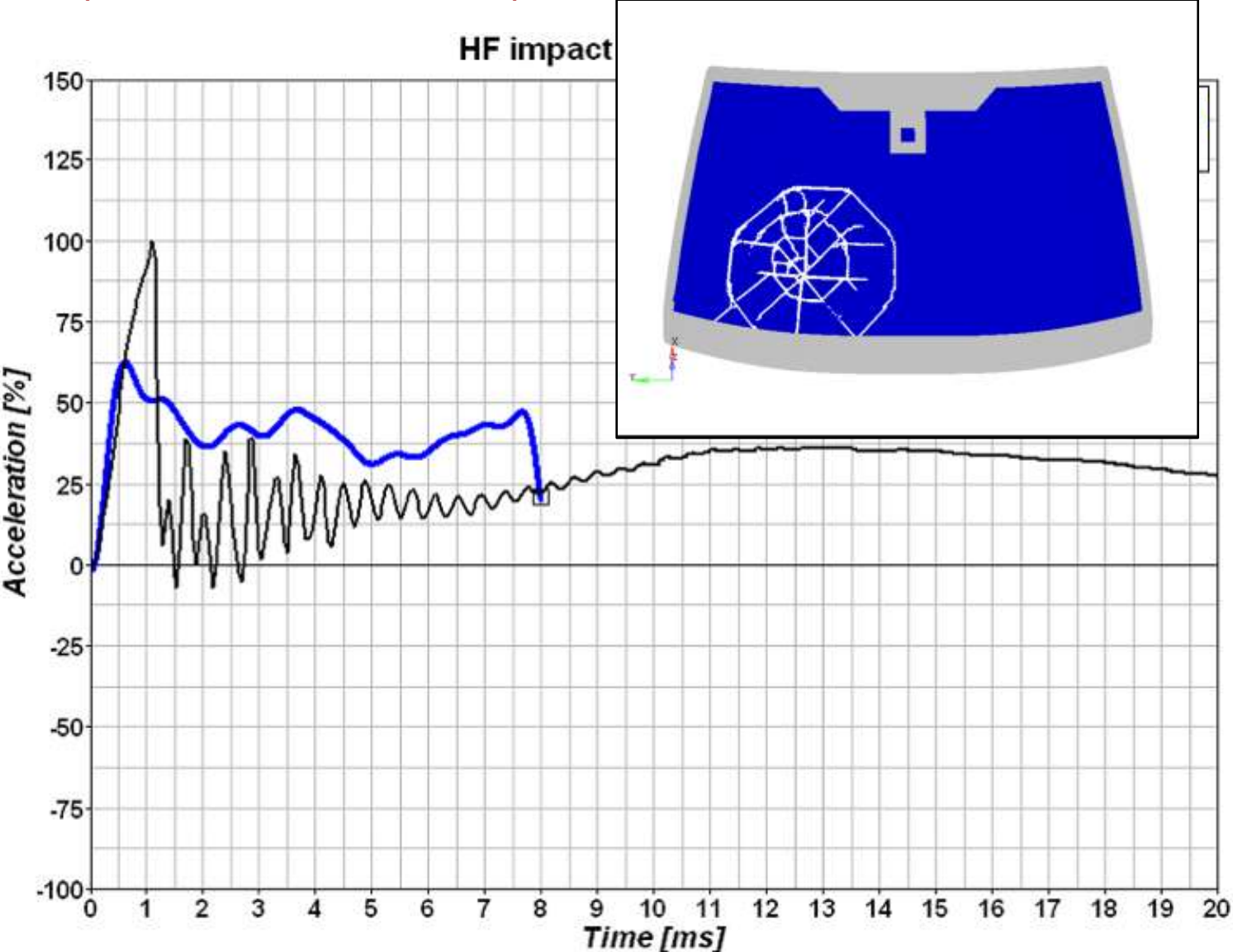
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■ Parameter study

Current status

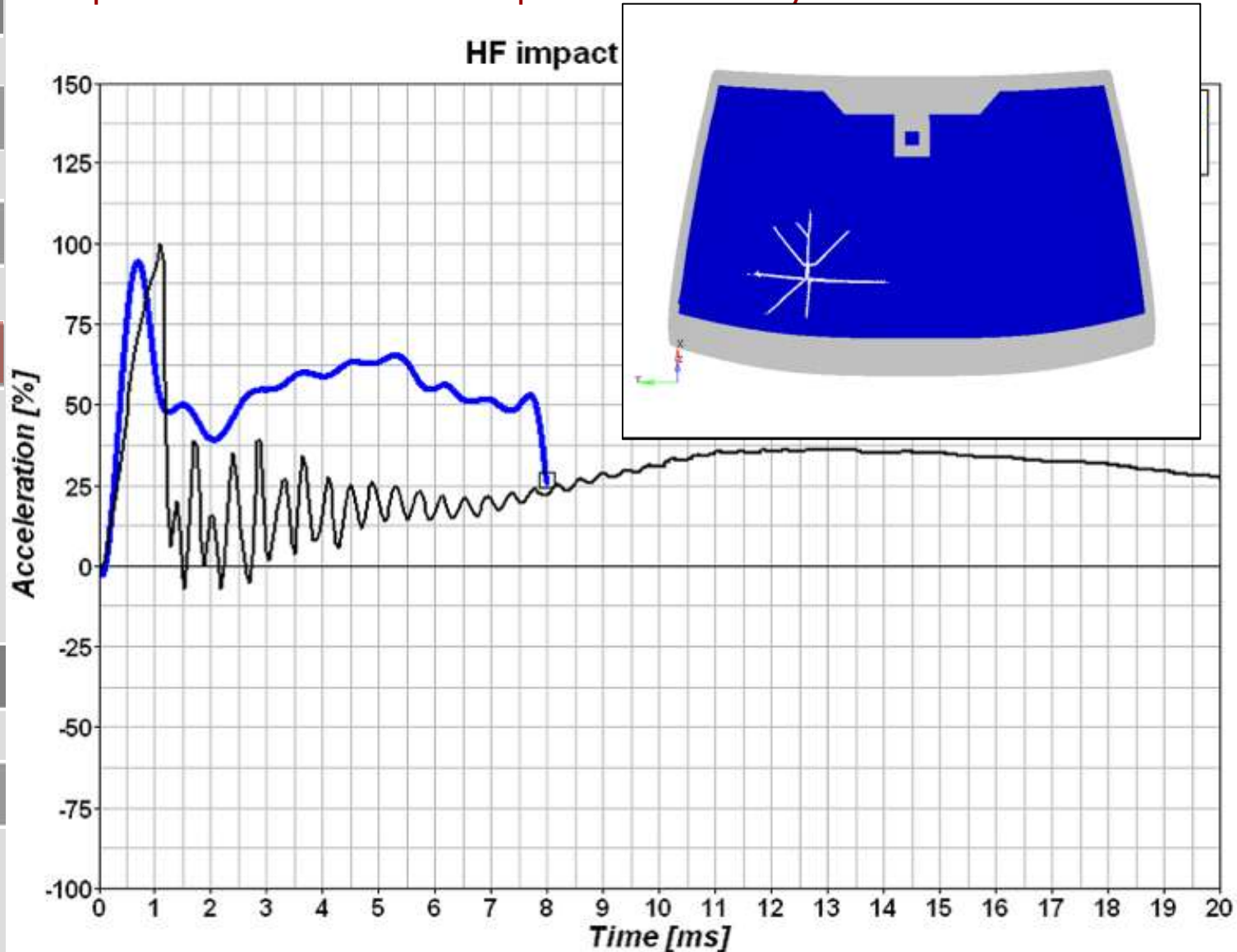


Conclusion



Outlook

## Improvements: automatic parameter study



 **TECOSIM**

 **Scope**

 **Status @EHTC'09**

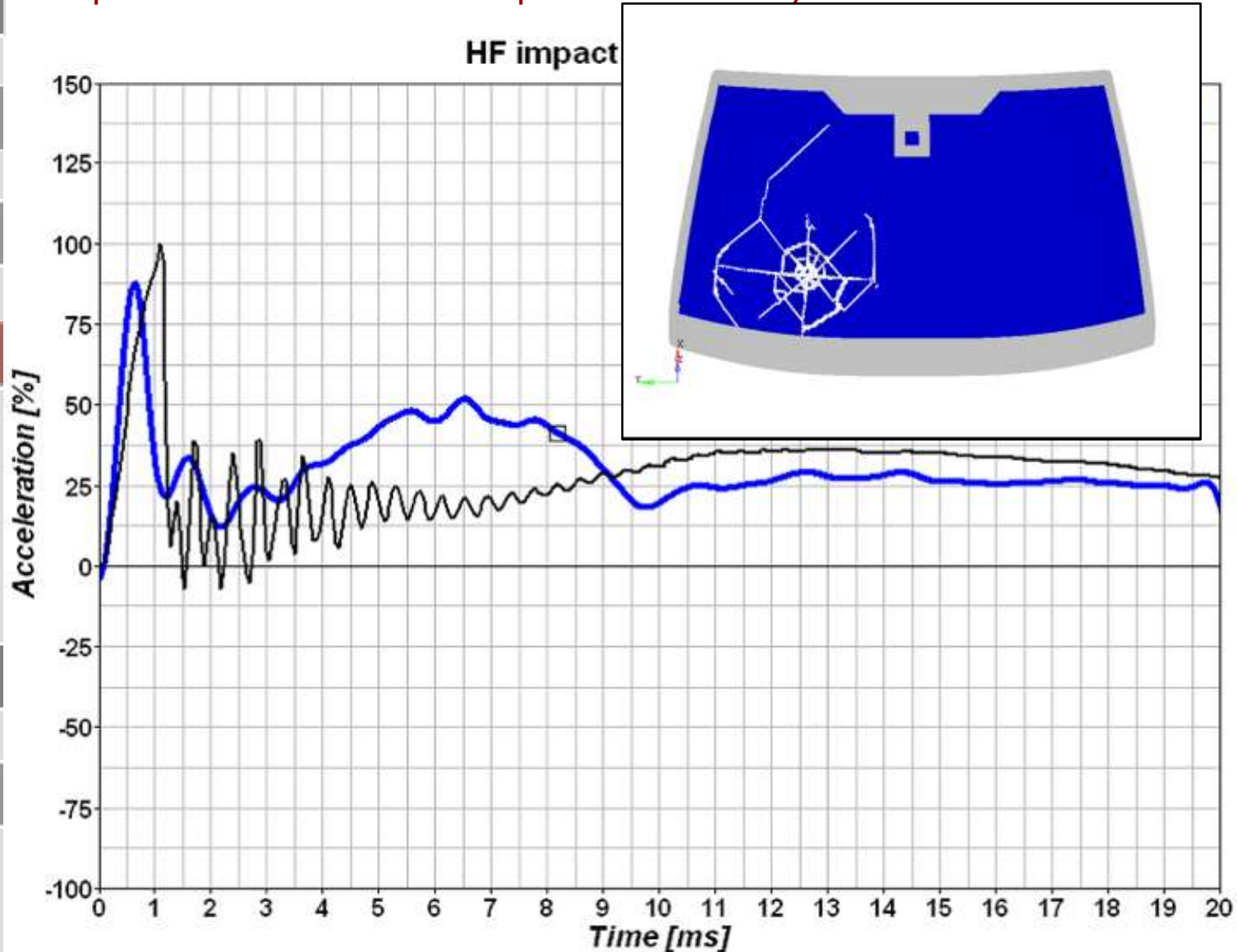
**Improvements**

- Influence cycle
- Pre-stresses
- PVB shear stiffness
- Glass properties
- **Parameter study**
- Current status

 **Conclusion**

 **Outlook**

## Improvements: automatic parameter study





TECOSIM



Scope



Status @EHTC'09



Improvements

Influence cycle

Pre-stresses

PVB shear stiffness

Glass properties

■ Parameter study

Current status

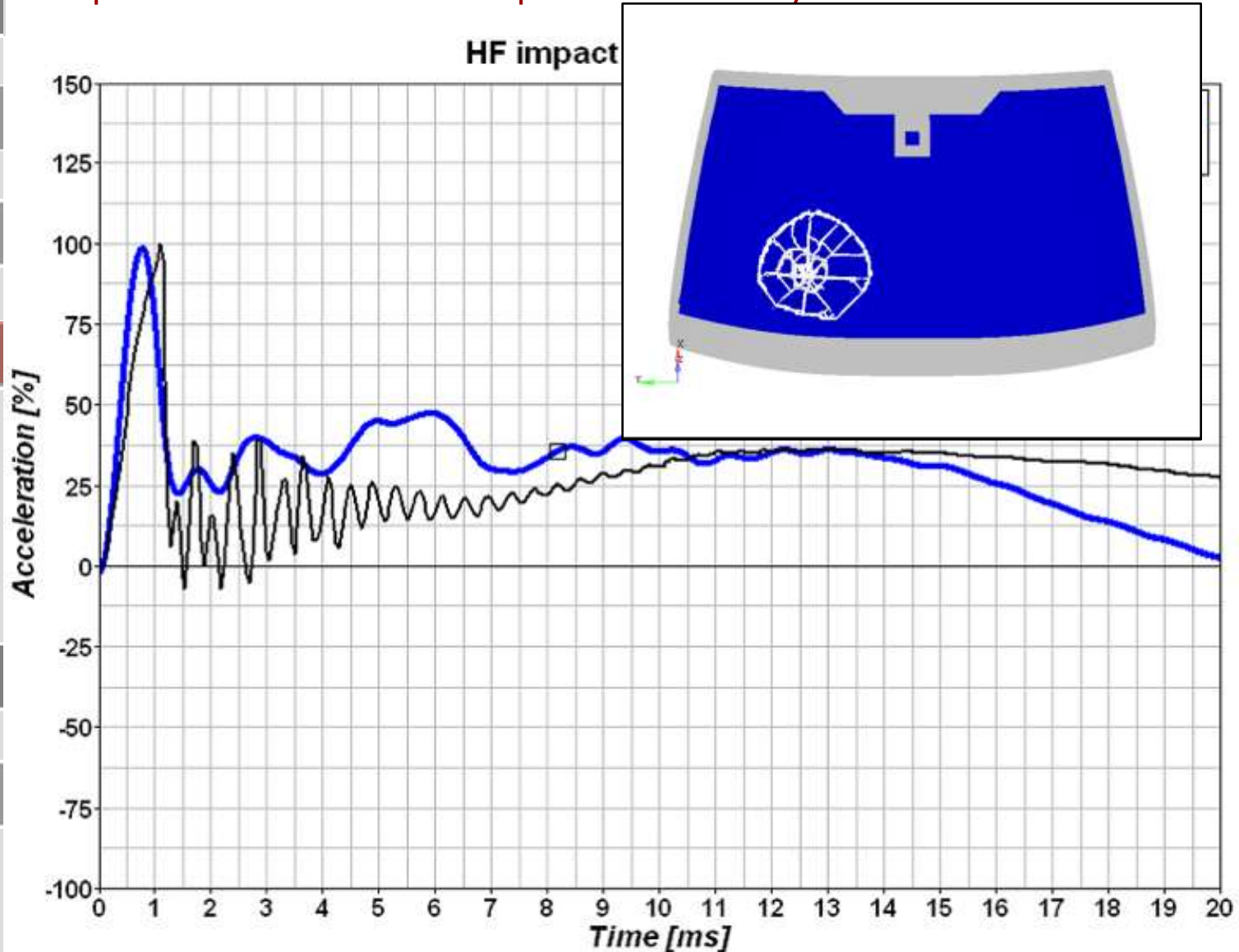


Conclusion



Outlook

## Improvements: automatic parameter study



 **TECOSIM**

 **Scope**

 **Status @EHTC'09**

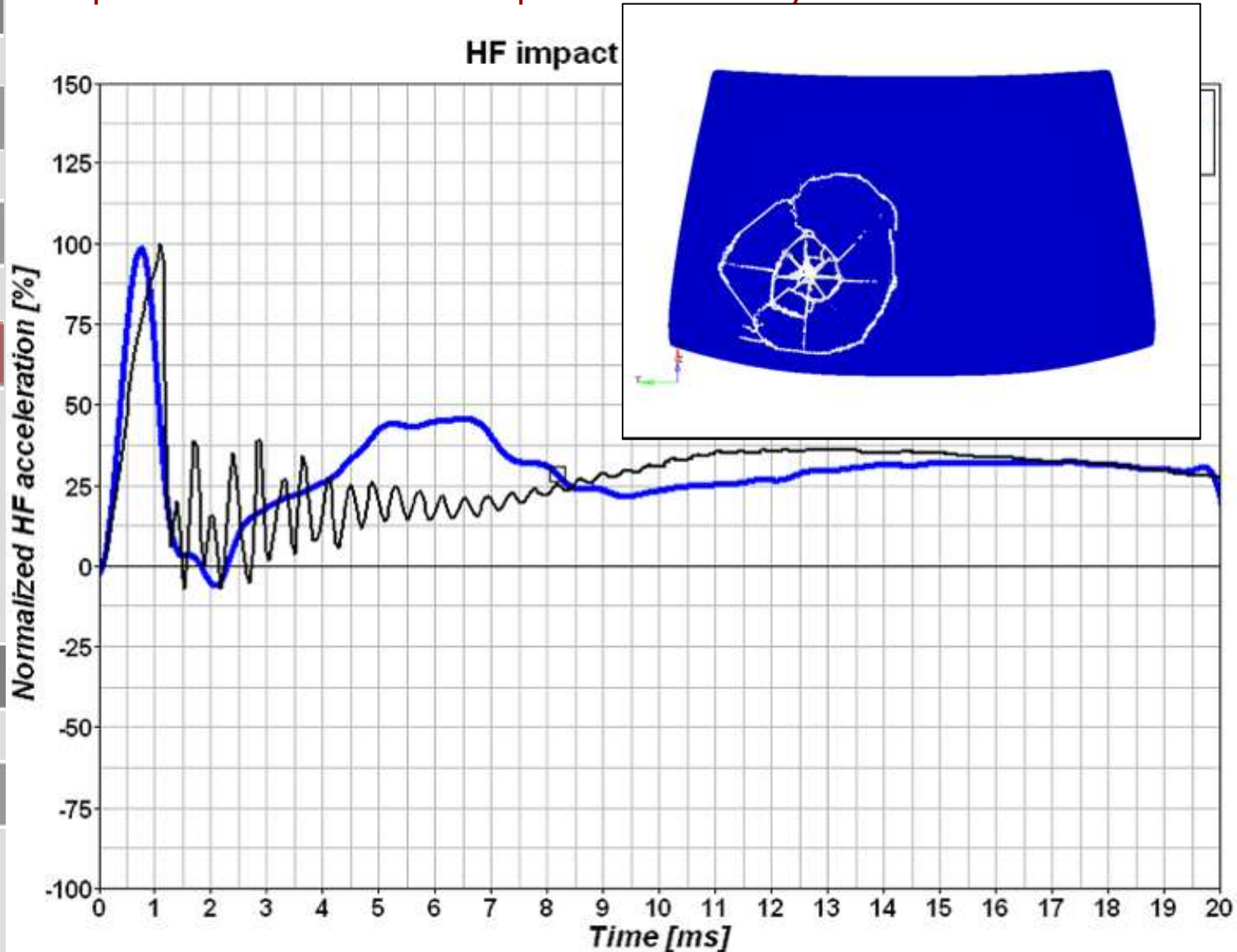
**Improvements**

- Influence cycle
- Pre-stresses
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## Improvements: automatic parameter study





TECOSIM



Scope



Status @EHTC'09



Improvements

- Influence cycle
- Pre-stresses
- PVB shear stiffness
- Glass properties
- Parameter study
- Current status



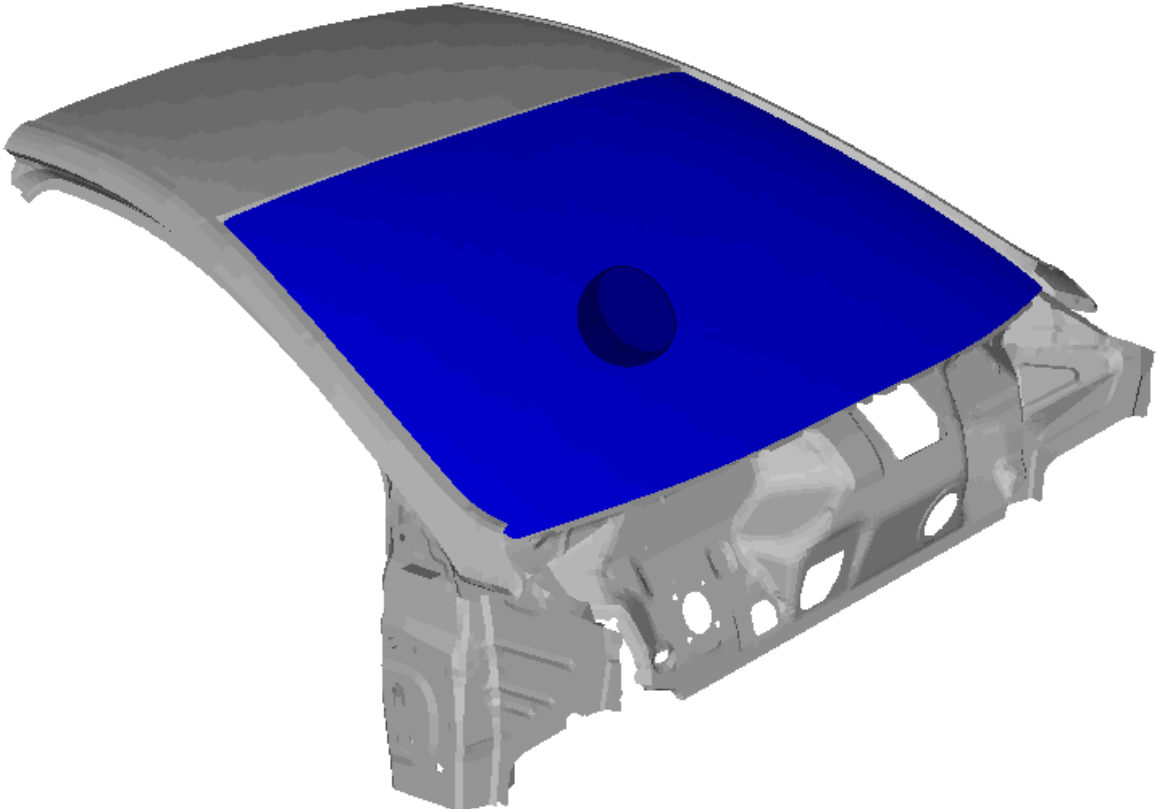
Conclusion

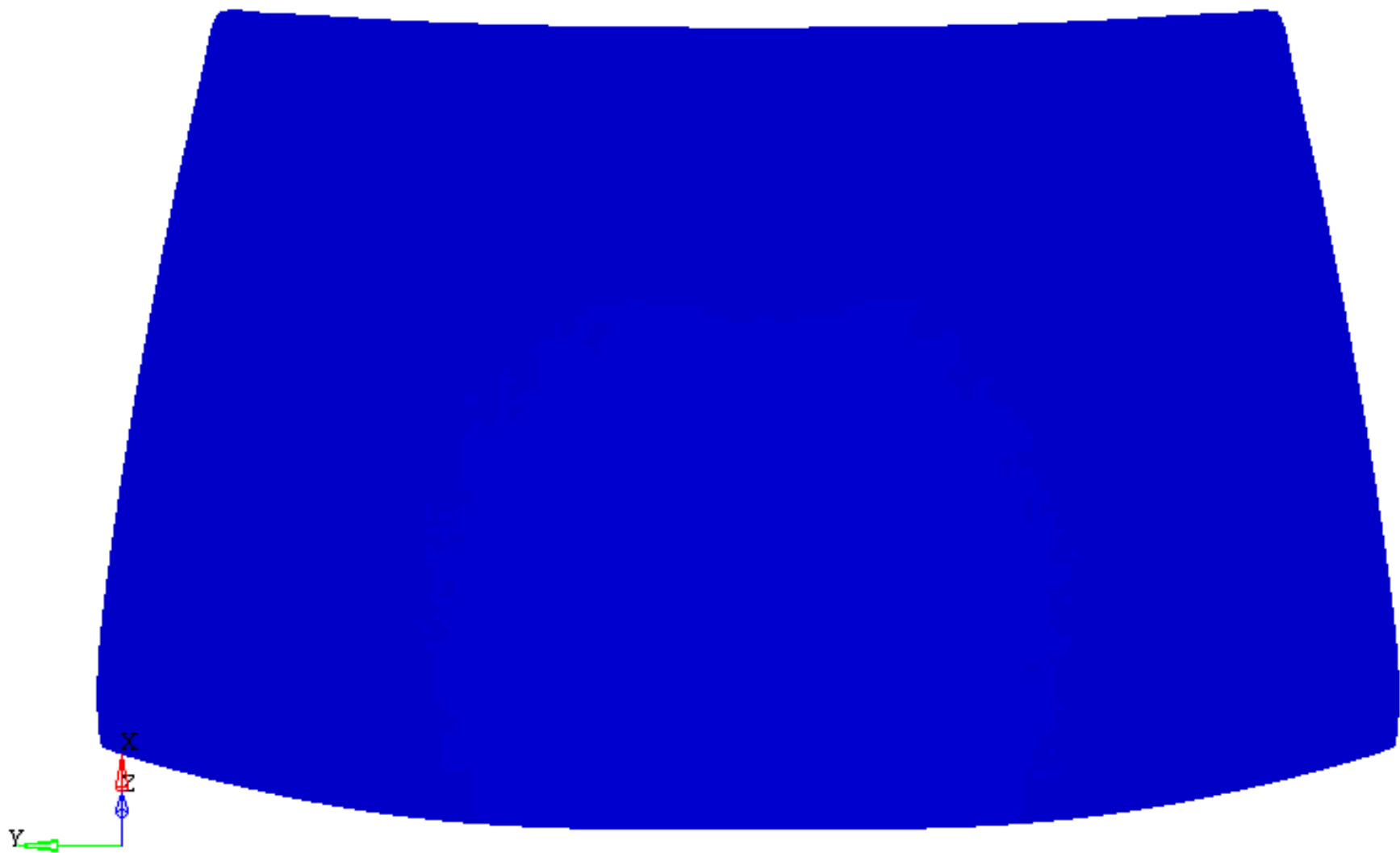


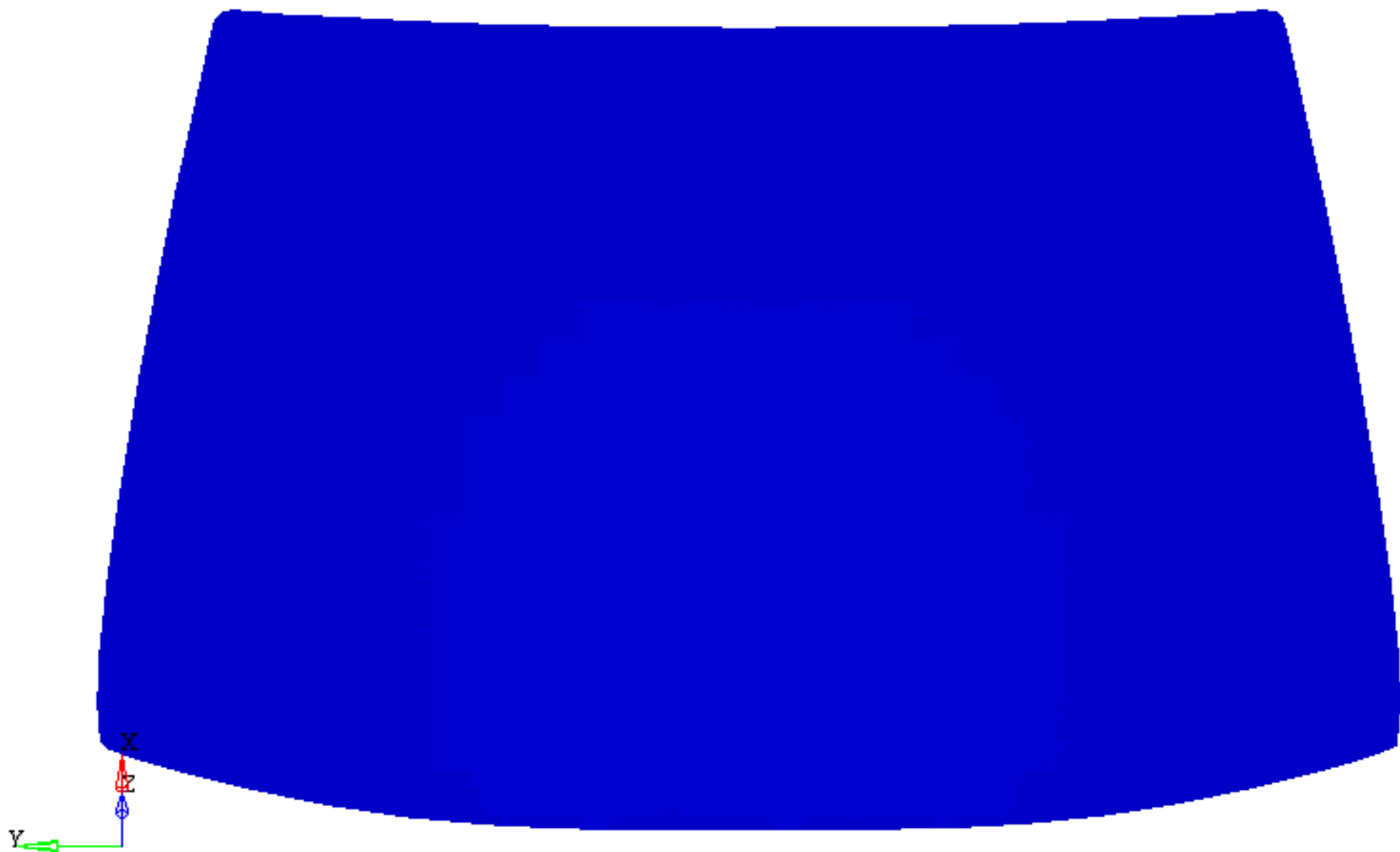
Outlook

Improvements: automatic parameter study

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TECOSIM



Scope



Status @EHTC'09



Improvements

Influence cycle

Pre-stresses

PVB shear stiffness

Glass properties

Parameter study

■ Current status



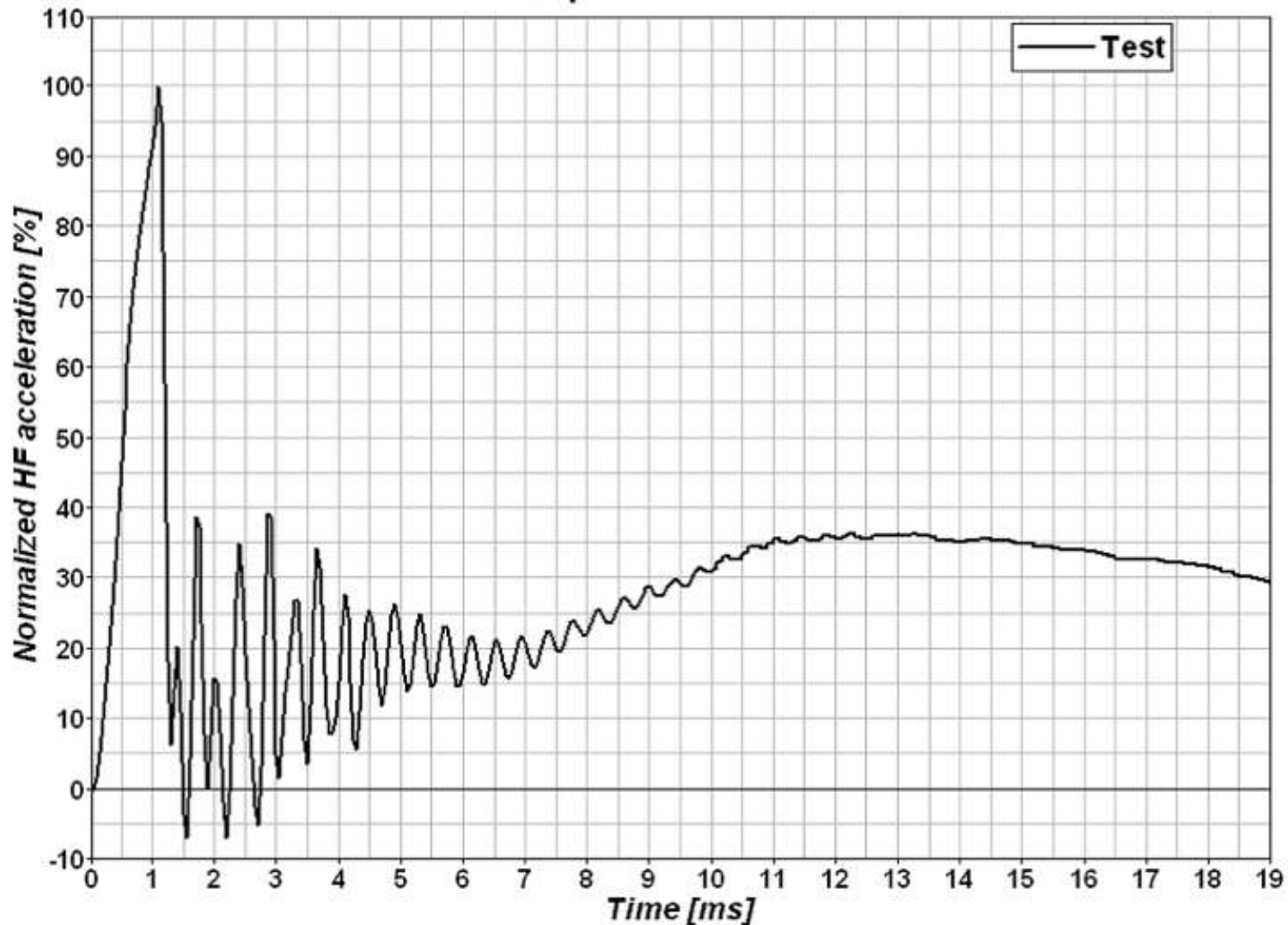
Conclusion



Outlook

## Improvements: current status of the RADIOSS results

HF impact on windscreen





TECOSIM



Scope



Status @EHCT'09



Improvements

- Influence cycle
- Pre-stresses
- PVB shear stiffness
- Glass properties
- Parameter study
- Current status

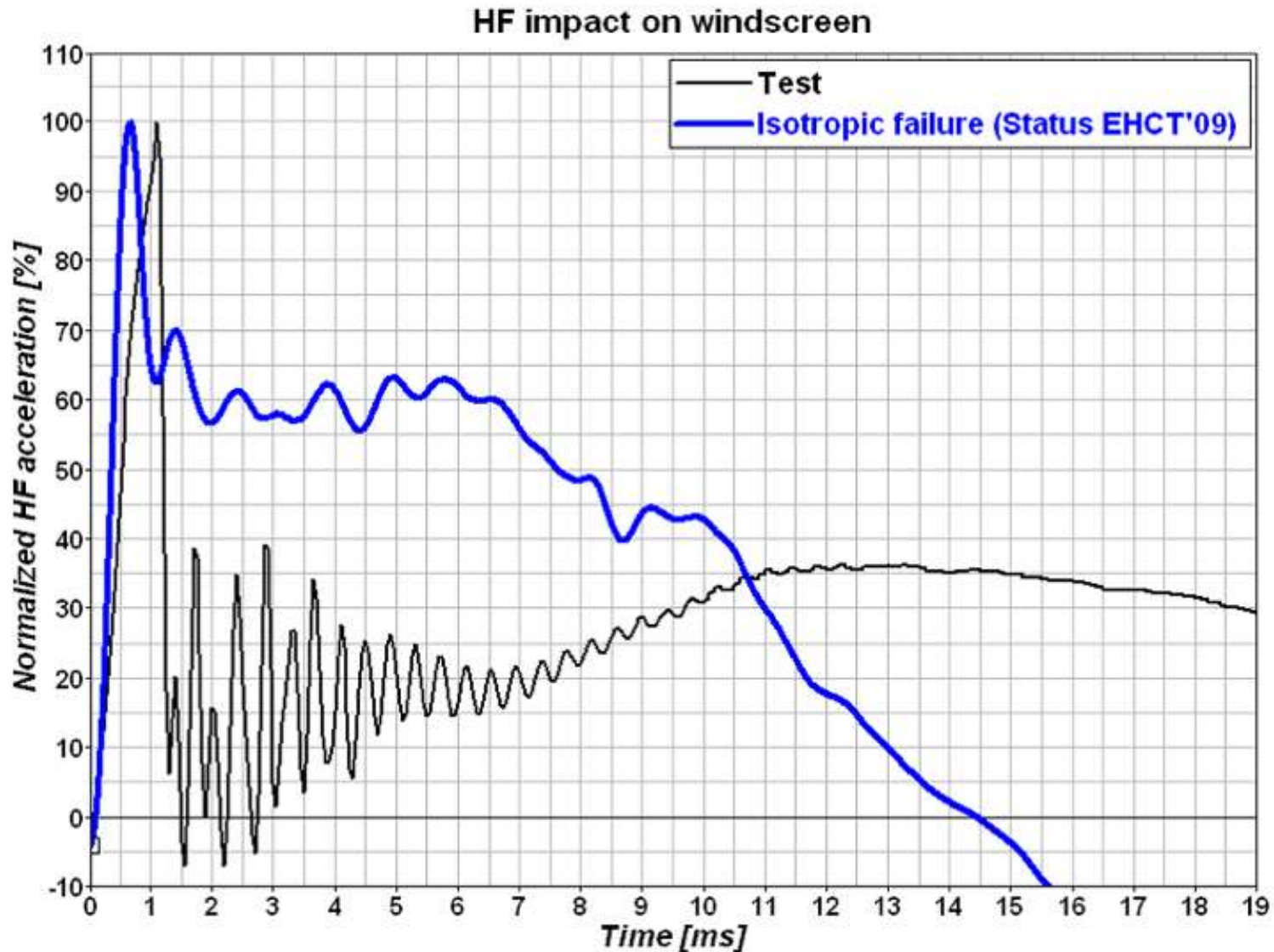


Conclusion



Outlook

## Improvements: current status of the RADIOSS results





TECOSIM



Scope



Status @EHTC'09



Improvements

- Influence cycle
- Pre-stresses
- PVB shear stiffness
- Glass properties
- Parameter study
- Current status



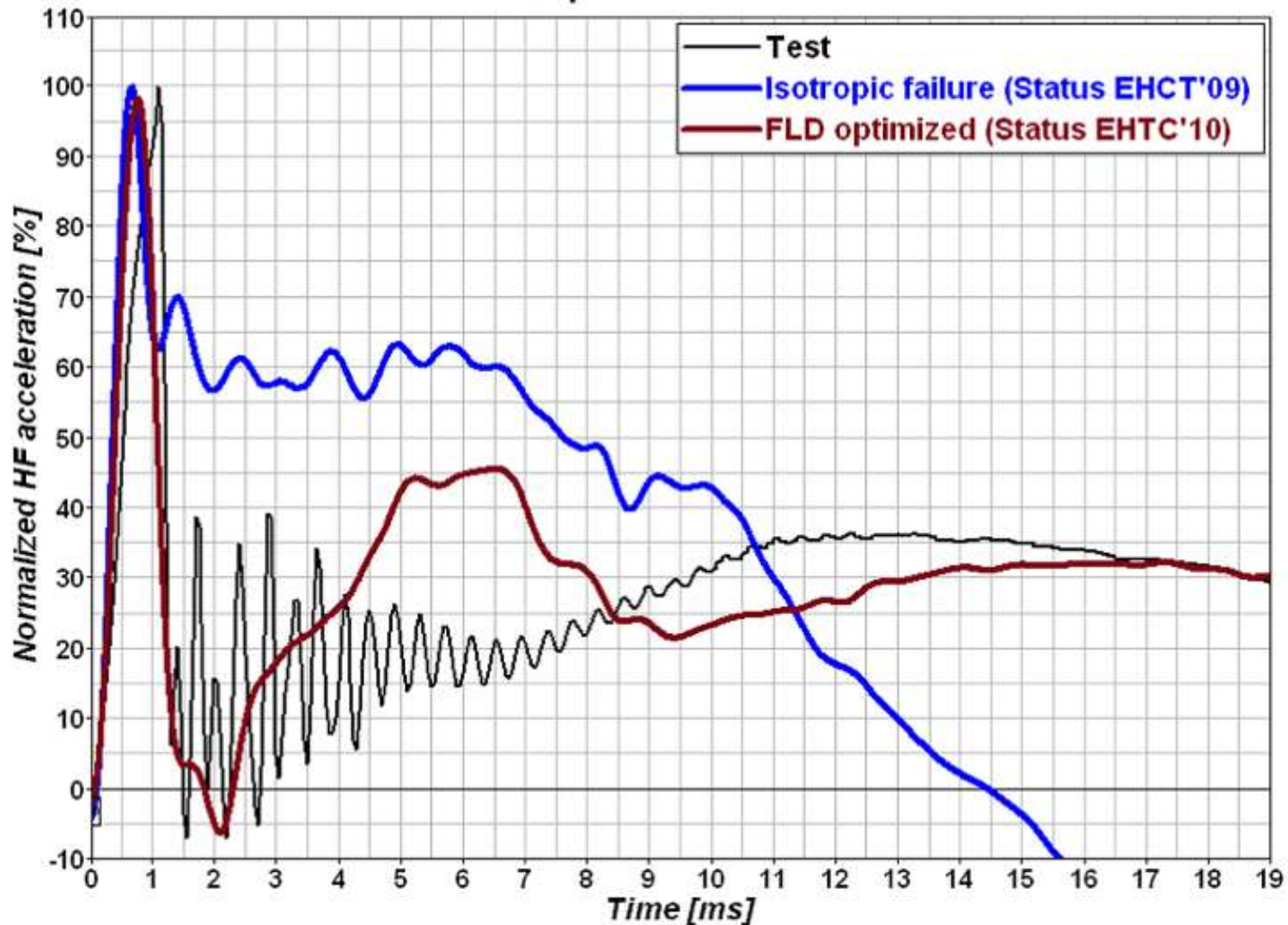
Conclusion



Outlook

## Improvements: current status of the RADIOSS results

HF impact on windscreen





TECOSIM



Scope



Status @EHTC'09



Improvements

- Influence cycle
- Pre-stresses
- PVB shear stiffness
- Glass properties
- Parameter study
- Current status

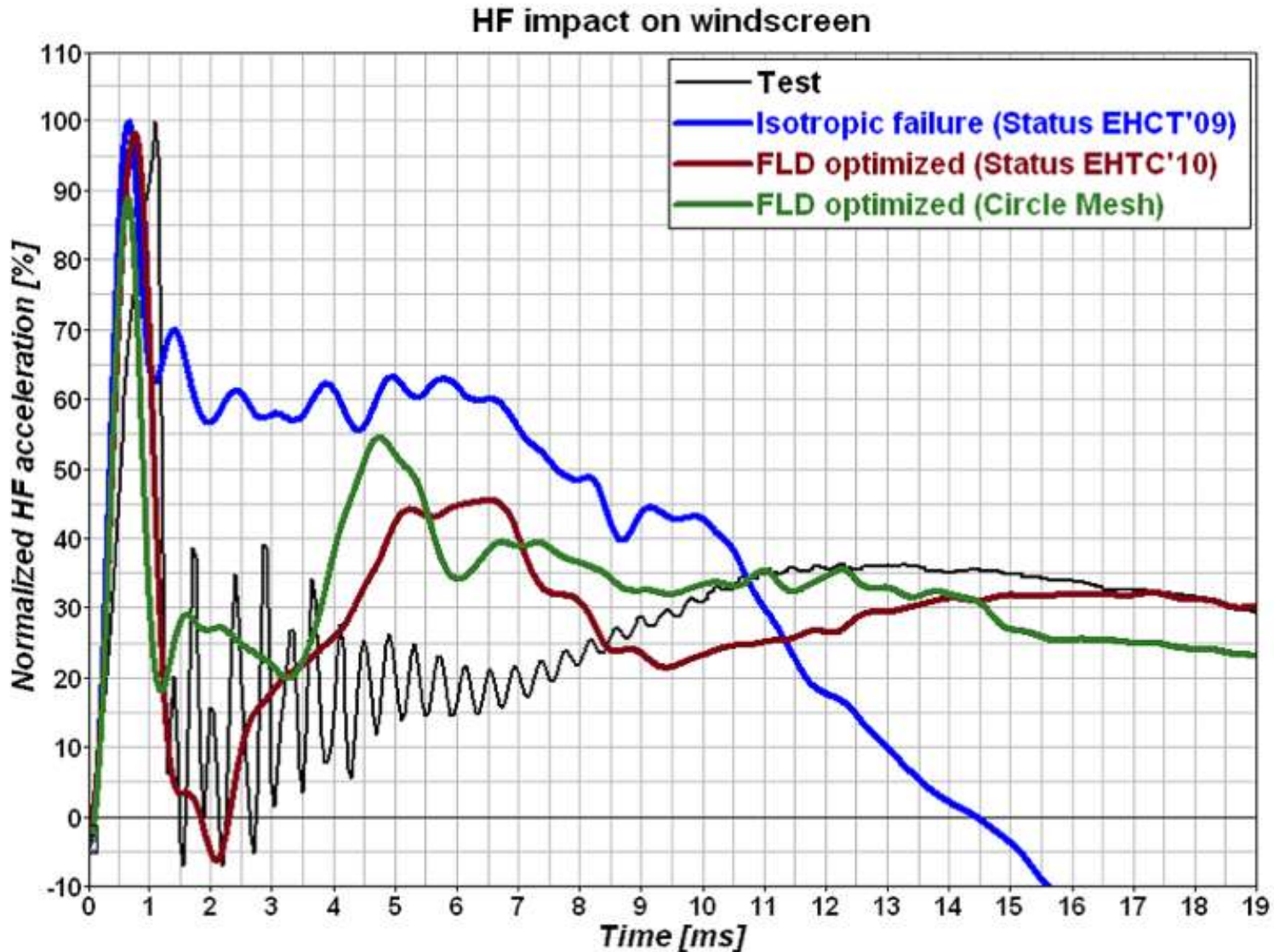


Conclusion

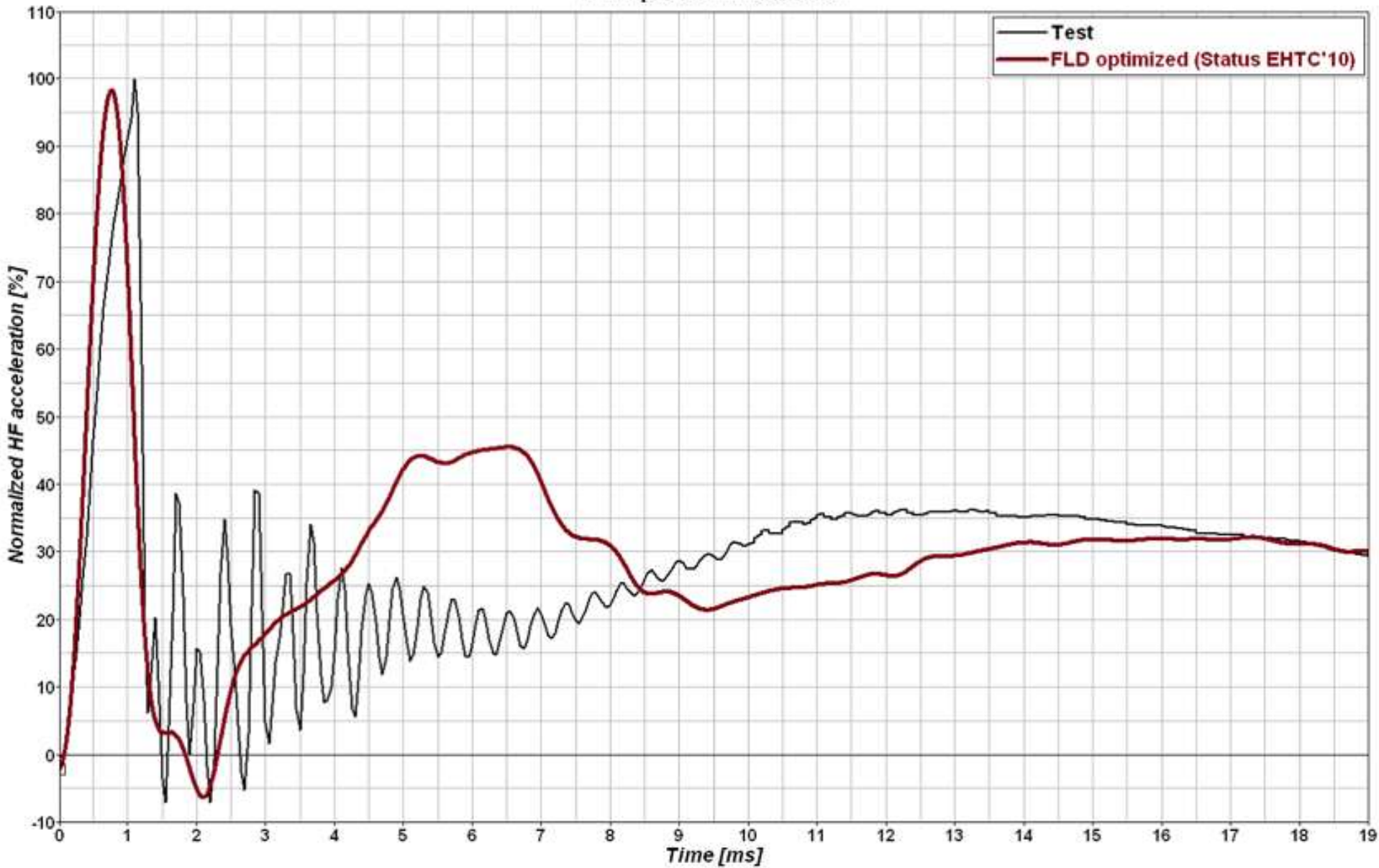


Outlook

## Improvements: current status of the RADIOSS results



HF impact on windscreen



TECOSIM

Scope

Status @EHTC'09

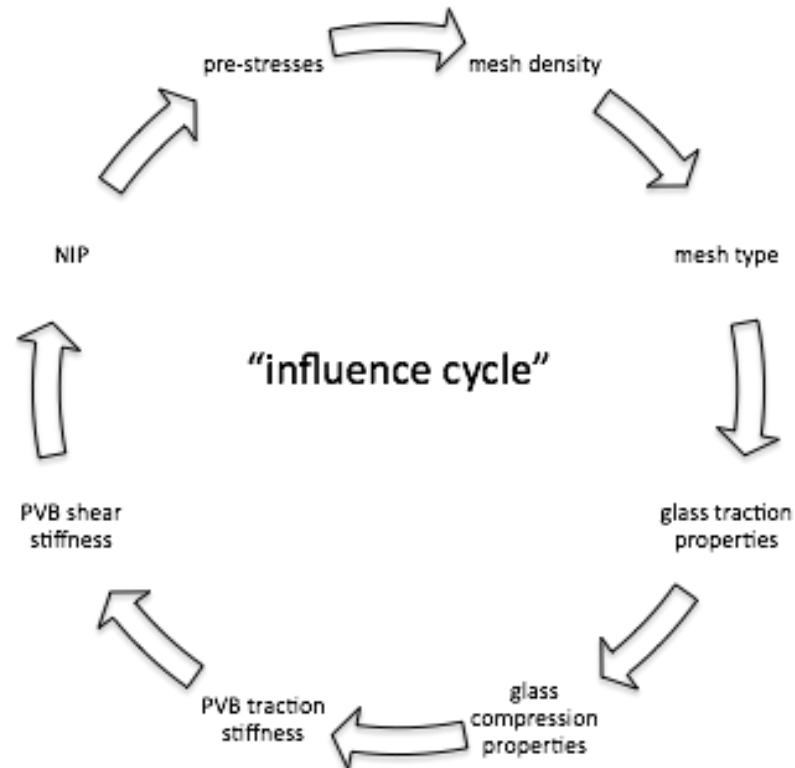
Improvements

Conclusion

Outlook

## Conclusion

- Based on the FORD R&D project TECOSIM makes further investigation to improve laminated glass model
- Several influence parameters were studied



TECOSIM

Scope

Status @EHTC'09

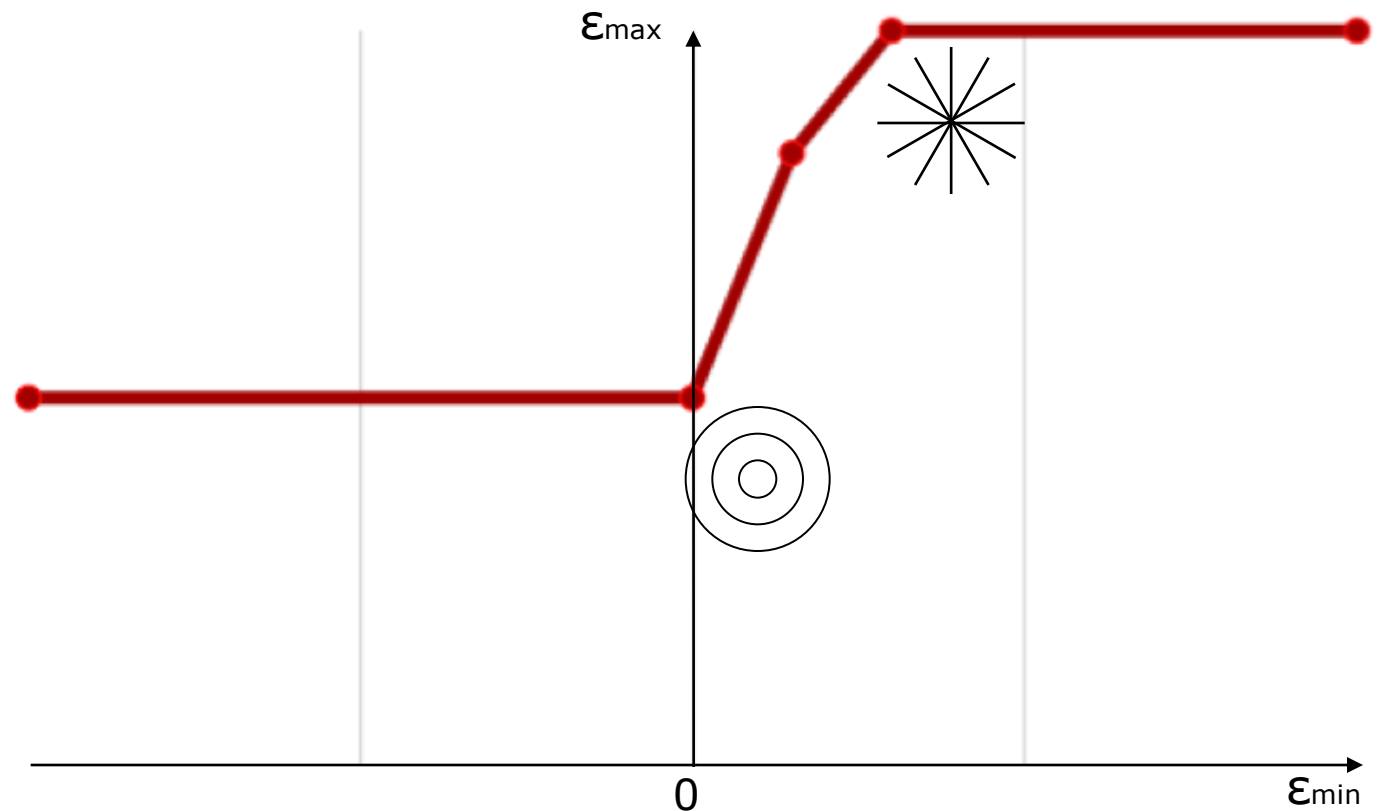
Improvements

Conclusion

Outlook

## Conclusion

- Based on the FORD R&D project TECOSIM makes further investigation to improve laminated glass model
- Several influence parameters were studied
- As main influence the non-isotropic rupture criteria of glass was detected



TECOSIM

Scope

Status @EHTC'09

Improvements

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## Conclusion

- Based on the FORD R&D project TECOSIM makes further investigation to improve laminated glass model
- Several influence parameters were studied
- As main influence the non-isotropic rupture criteria of glass was detected
- A usable model was generated respecting:
  - full vehicle crash time step
  - simulation turn around time
  - easy handling (meshing guide-line and material / property set)



TECOSIM

Scope

Status @EHTC'09

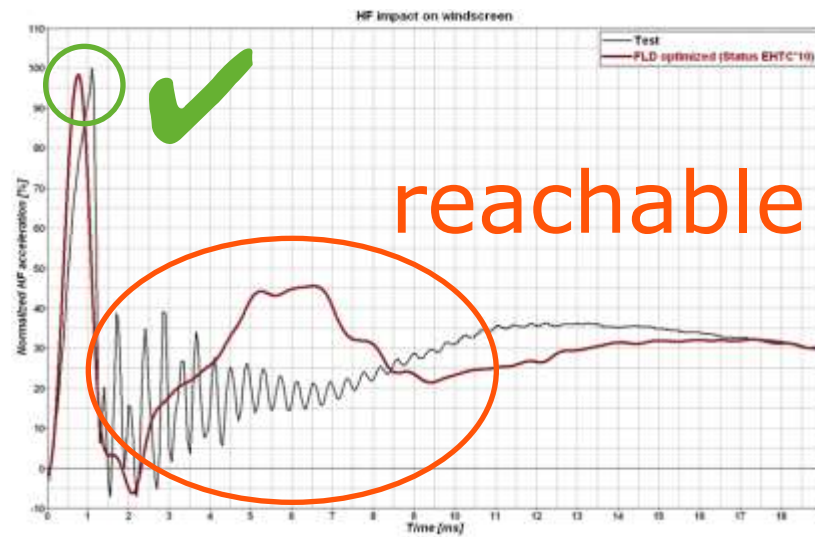
Improvements

Conclusion

Outlook

## Outlook

- TECOSIM establishes a parameter optimization process to reach test results: now additional parameters can be investigated
- Mesh independent crack distribution will be studied (X-FEM method)
- The model will be carried over to the three other explicit codes (LS-DYNA, PAM-CRASH, ABAQUS)
- All models will be finalized in spring 2011
- Target:
  - load level difference simulation to test <2% for the first peak
  - load level difference simulation to test <10% after the first peak



Thanks to



# Thanks to

Gefördert durch:



Bundesministerium  
für Wirtschaft  
und Technologie

aufgrund eines Beschlusses  
des Deutschen Bundestages



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Scope



Status @EHTC'09



Improvements



Conclusion



Outlook

stay tuned  
more to come in spring 2011

please visit [www.tecosim.com](http://www.tecosim.com)



## Contact

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